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(Fig. 1A-D, Fig. 2C)

Cordium hions Brocchi, 1814: p. 508, tav. 13, fig. 6 (non Spengler, 1799).
Cordium indicum Lamarck, 1819: p. 4.
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Salas C., 1996. Marine Bivalves from off the Southern Iberian Peninsula collected by the Balgim and Fauna 1 expeditions. *Holiotis*, **25**: 33-100.
Grill B. & Zuschin M., 2001. Modern shallow- to deep-water bivalve death assemblages in the Red Sea - ecology and biogeography. *Poloeogeography, Poloeoclimotology, Poloeoecology*, **168**: 75-96.
Boss K.J., 1982. Mollusca, in Parker S.P. (ed.), *Synopsis ond Clossificotion of Living Orgonisms*. Vol. 1. McGrow-Hill, New York: 945-1166.
Carter J.G., Campbell D.C. & Campbell M.R. 2000. Cladistic perspectives on early bivalve evolution, in Harper E.M., Taylor J.D. & Crame J.A. (eds), The Evolutionary Biology of the Bivalvia. *Geologicol Society, London, Speciol Publicotions*, **177**: 47-95.
Vokes H.E., 1980. *Genero of the Bivolvio: o systemotic ond bibliogrophic cotologue (revised ond updote)*. Paleontological Research Institution, Ithaca, Edwards Brothers Inc., 307 pp.

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Land molluscs of forest habitats of four "Natura 2000" sites in Emilia-Romagna, with notes on the date of settlement of the alien species *Bulgarica denticulata*

Paolo G. Albano*° (✉), Viller Bassi#, Pamela D'Occhio*, Grazia Strazzari°, Fabio Succetti* & Bruno Sabelli*

* Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Università di Bologna, Via Selmi 3, 40126 Bologna, Italy

Società Reggiana di Scienze Naturali, Via A. Gramsci 109, 42024 Castelnovo di Sotto (RE), Italy

° NIER Ingegneria SpA, via C. Bonazzi 2, 40013 Castel Maggiore (BO), Italy

✉ corresponding author: pgalbano@gmail.com

Abstract

This paper describes the land mollusc fauna of four "Natura 2000" sites in the Emilia-Romagna region, northern Italy. The study sites are located along an altitudinal transect and host different forest types. Study sites include a coastal site (Pineta di Classe), a lowland site (Ripristini di Bentivoglio), an area between the river Reno and the nearby hills (Destra Reno), and a montane site on the watershed with Toscana (Lago Brasimone). Fifty-eight species were found, approximately 11% of the Italian land mollusc fauna and 48% of the estimated fauna of Emilia-Romagna. The fauna has a strong continental affinity, with some Mediterranean elements more common in the coastal site. Among the species of conservation interest there is *Vertigo angustior* found as several empty shells at Pineta di Classe and at Destra Reno. We confirm the presence of the alien species *Bulgarica denticulata* in the pine woodlands near Ravenna (Pineta di Classe) but we hypothesize that its settlement could be a more recent event than suggested in the literature to date: no records of species referable to this taxon could be found in the 18th century literature on the molluscs of Ravenna and its nearby pine woodlands, suggesting that the arrival of this alien species in Italy could be dated between the end of the 18th century and the beginning of the 19th century.

Key Words

Land molluscs, Italy, Emilia-Romagna, *Bulgarica denticulata*, alien species.

Riassunto

[*Molluschi continentali da ambienti forestali di quattro siti "Natura 2000" in Emilia-Romagna, con note sui tempi di introduzione della specie aliena* Bulgarica denticulata]. Si descrive la fauna dei molluschi terrestri rinvenuti negli ambienti forestali di quattro siti "Natura 2000" dell'Emilia-Romagna. La collocazione dei siti lungo un transetto altitudinale che ospita diverse formazioni forestali ha permesso di massimizzare la diversità specifica rinvenuta. I siti studiati includono una pineta costiera (Pineta di Classe), un sito di pianura (Ripristini di Bentivoglio), un'area tra il fiume Reno e le colline prospicienti (Destra Reno) e un sito montano prossimo al confine con la Toscana (Lago Brasimone). Sono state rinvenute 58 specie che costituiscono circa l'11% della fauna italiana e il 48% della fauna regionale. La fauna presenta una forte affinità continentale con il 68,4% delle specie a distribuzione centro-europea. Il rimanente 31,6% delle specie è invece ristretto all'Europa meridionale. Quattro specie hanno una distribuzione totalmente o prevalentemente ristretta alla penisola italiana: *Arion* cf. *franciscoloi*, noto dalla Liguria orientale e dall'Appennino Settentrionale; *Retinella olivetorum*, nota per la penisola italiana e una stazione in Francia meridionale; *Vitrea etrusca*, nota per l'Italia centrale e settentrionale, nonché dalla Corsica; e *Chilostoma planospira*, nota da gran parte dell'Italia. Poche sono le specie rinvenute che hanno avuto una valutazione del loro stato di conservazione. Sulla base della recente valutazione a livello europeo, 27 delle specie rinvenute (il 42.9%) non destano preoccupazione, *C. planospira* è considerata troppo carente di dati per la valutazione, *Chondrula tridens* è invece considerata quasi minacciata, e *Vertigo angustior* vulnerabile (ed è l'unica specie compresa nell'Allegato II alla Direttiva "Habitat", che elenca le specie che necessitano della designazione di zone speciali di conservazione). Di quest'ultima specie sono stati trovati diversi nicchi vuoti sia alla Pineta di Classe che in Destra Reno. Si conferma inoltre la presenza della specie aliena *Bulgarica denticulata* presso la Pineta di Classe. È stato ipotizzato che questa specie sia stata introdotta in Romagna ai tempi dell'Impero Bizantino, ma la letteratura malacologica del diciottesimo secolo non elenca e illustra alcuna specie riferibile a questa entità. Pertanto, riteniamo che la data di arrivo della specie sia successiva a quanto ipotizzato finora e databile tra la fine del diciottesimo e l'inizio del diciannovesimo secolo.

Parole Chiave

Molluschi continentali, Italia, Emilia-Romagna, *Bulgarica denticulata*, specie aliene.

Introduction

Invertebrates are often neglected in conservation policies notwithstanding they constitute the great majority of biodiversity (Ponder & Lunney, 1999). Major impediments to their protection include (Cardoso et al., 2011): poor public awareness, poor policymakers and stakeholders awareness, insufficient basic knowledge such as distribution and abundance, an high number of species still to be described even in presumed well known areas like Europe (Fontaine et al., 2012) and poor knowledge on species way of life and sensitivities to habitat change. Molluscs do not make an exception to this rule. Moreover, 42% of the 693 recorded extinctions since the year

1500 are molluscs (Lydeard et al., 2004) and even more go unnoticed (Régnier et al., 2009). Non-marine molluscs constitute 99% of all molluscan extinctions.

Among the objectives of the European Union Council Directive 92/43 "Habitat" there is to contribute towards ensuring biodiversity through the conservation of natural habitats and of wild fauna and flora in the European territory of the EU Member States. Species conservation is sought by identifying species "of community interest" (Annex II) or "in need of strict protection" (Annex IV) and designating special areas of conservation for the former, and enforcing prohibition of capture, killing, disturbance and trade for the latter. It is recognized that the species listed in the annexes of the Directive are poorly representative of present day conservation priorities (Bouchet et al., 1999) and often not adequately representative of European threatened biodiversity (Cardoso, 2012). However, invertebrates and continental molluscs in particular may indirectly benefit from the habitat protection enforced (which in any case is limited to a selection of habitats).

In this context, faunal studies targeting land molluscs represent a tentative to fill the knowledge gap of species distribution and abundance. The present work is based on extensive sampling in four "Natura 2000" sites in the Emilia-Romagna region, northern Italy. Sites were selected as being representative of the local major bioclimatic regions: the coast, the lowland, the riverine and hilly countryside, and the mountains. Intense sampling mainly targeted woodlands, because they are among the few natural habitats still present in the region, especially in lowland, and host the great majority of land snail species (Kerney & Cameron, 1979). However, non-quantitative sampling was carried out also outside these habitats, mainly going to and coming back from woodland sampling sites.

Previous knowledge of Emilia-Romagna land snails is exceptionally scarce and mainly dating back to the 19th century (e.g. Strobel, 1878 and the work on his collection by Bellavere & Peretti (1984); Picaglia, 1892). Among the few modern works, there are the check-list of molluscs of the province of Modena (Palazzi, 1985), a few tens of kilometres west of the study sites, and that of Zangheri (1969) listing species found in Romagna, the eastern part of the region, enclosing the coastal site included in this study. No modern works were found for the province of Bologna, where the three non-coastal sites are located. Further data can be found in very limited quantity in the material examined by taxonomic work.

Therefore, the objectives of this work are: i) to describe the molluscan fauna of these sites, contributing to the knowledge of invertebrates in the Natura 2000 network, ii) to highlight the presence of any molluscan endemic species, species of conservation interest or alien species, and iii) to provide baseline biodiversity information for future assessment of conservation efforts efficacy. The paper will also discuss the date of first settlement of the alien species *Bulgarica denticulata* (Olivier, 1801).

Materials and methods

Study area

The study was conducted in four "Natura 2000" sites of the Emilia-Romagna region along an altitudinal transect: SCI-SPA IT4070010 "Pineta di Classe" (in the province of Ravenna), SCI-SPA IT4050024 "Biotopi e ripristini ambientali di Bentivoglio, San Pietro in Casale, Malalbergo e Baricella", SCI-SPA IT4050029 "Boschi di San Luca e Destra Reno" and SCI 4050020 "Laghi di Suviana e Brasimone" (all in the province of Bologna) (**Fig. 1**). In the following text, it will be referred to the sites respectively as "Pineta di Classe", "Ripristini di Bentivoglio", "Destra Reno", "Lago Brasimone" for sake of brevity, and we will always refer only to the forested habitats therein.

Pineta di Classe is a coastal woodland of 0.11 km^2. Its surface is mostly covered by pine and oak woodland (*Pinus pinea*, *Pinus pinaster* and *Quercus ilex*). Soil is sandy and calcareous.

Ripristini di Bentivoglio is a lowland site (maximum 17 m a.s.l.), originally covered by marshes until the 18th century, then reclaimed and used for rice fields until mid-20th century. Here woodlands are mostly composed by poplar and willow (*Populus alba* and *Salix alba*), and sampling was concentrated in these areas. Soil is calcareous.

Destra Reno is a diverse site on the hills south of Bologna, with two main habitats: a poplar woodland (*Salicetum albae* formation) along the right side of the Reno River, and an oak or hornbeam and maple woodland (*Knautio-Quercetum pubescentis* and *Ostryo-Aceretum opulifolii*) on the hills above. The river woodland lays between 50 and 70 m a.s.l., while the oak woodland lays between 80 and 370 m a.s.l. In the presentation of results, species preference for one or the other habitat will be highlighted. Soil is calcareous.

Lago Brasimone is a site on the Apennines, near the watershed with Toscana. It has the greatest elevation range, from 600 to 1,250 m a.s.l. The site is covered by extensive almost pure beech forests (*Fagus sylvatica*) and by other deciduous trees like oak (*Quercus cerris*, *Quercus pubescens*), hornbeam (*Ostrya carpinifolia*, *Carpinus betulus*) and chestnut (*Castanea sativa*) forests. Soils are mostly acidic.

Sampling and sorting techniques

Sampling was carried out mainly with a quantitative approach. Areas of 1 km^2 with homogeneous habitat cover were randomly located and will be here called sampling stations. At each station, two collecting methods were used: time-constrained visual search, and leaf litter and soil collecting and sorting. The former was carried out on three 10 × 10 m squares. Each square was searched by a single operator for 30 minutes. The latter was performed by collecting 2 litres of litter and soil down to 2 cm for five replicate. Samples were air dried and sieved down to 0.5 mm mesh. Fractions above 1 cm were searched by eye while those below under a micro-

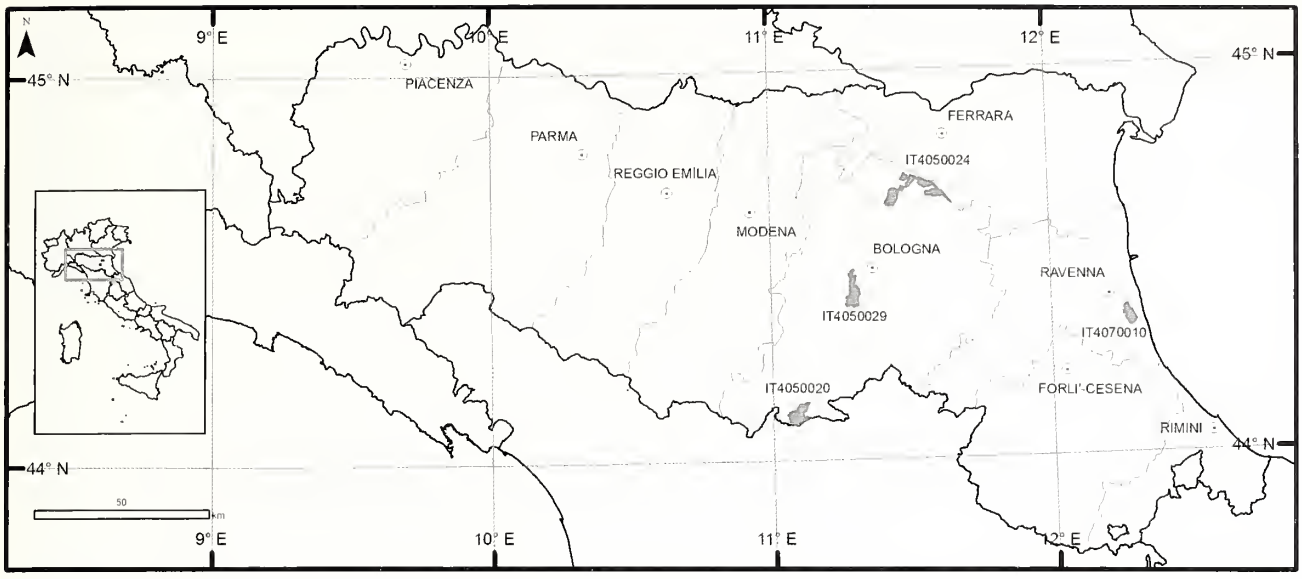

Fig. 1. Location of the study sites in the Emilia-Romagna region: SCI-SPA IT4070010 "Pineta di Classe", SCI-SPA IT4050024 "Biotopi e ripristini ambientali di Bentivoglio, San Pietro in Casale, Malalbergo e Baricella", SCI-SPA IT4050029 "Boschi di San Luca e Destra Reno" and SCI 4050020 "Laghi di Suviana e Brasimone".

Fig. 1. Posizione dei siti Natura 2000 studiati nella Regione Emilia-Romagna: SIC-ZPS IT4070010 "Pineta di Classe", SIC-ZPS IT4050024 "Biotopi e ripristini ambientali di Bentivoglio, San Pietro in Casale, Malalbergo e Baricella", SIC-ZPS IT4050029 "Boschi di San Luca e Destra Reno" e SIC 4050020 "Laghi di Suviana e Brasimone".

stereoscope. Samples were taken outside the areas of the visual search. Three visual search replicates and five soil and litter samples were collected at each station. Replicates were collected at sites distant one from each other between 10 and 50 m. Twenty stations were inspected at each site by visual search (only 5 at Ripristini di Bentivoglio due to the limited habitat extension) and 15 stations were inspected by leaf litter and soil sorting (again only 5 at Ripristini di Bentivoglio). On the way to and from quantitative sampling sites, qualitative search was carried out too.

Field activities were conducted in spring, from April to early June 2012, when favourable climatic conditions (rainfall, humidity) enhance the activity and therefore detectability of molluscs. Moreover, all visual searches were carried out during day light. This might have a reduced efficacy for slugs (Wäreborn, 1969) which are more active at night but is not expected to significantly affect the results for snails (Ward-Booth & Dussart, 2001).

Identification and taxonomy

Identification was carried out mostly to the species level, without inspection of the soft parts. Groups with little taxonomic knowledge, or for which our material did not allow definitive identifications were treated with a lumping approach and use of the "cf." or "sp." notation. Nomenclature follows the Fauna Europaea project (Fauna Europaea, 2012). The systematic arrangement follows Bodon et al. (1995) for Prosobranchia and Manganelli et al. (1995) for Pulmonata. Distributional data at the European scale mainly originates from Welter-Schultes (2012). When quoting from other Authors' papers we have kept the binomen they used. All the material here described is stored in the Museo di Zoologia dell'Università di Bologna (MZUB).

The study is based on the ca. 23,000 specimens, 8,384 of which were collected alive.

Abbreviations
sh(s): empty shells
spm(s): live collected specimens

Results

Class Gastropoda Cuvier, 1795
Family Aciculidae Gray, 1850
Platyla stussineri (O. Boettger 1884)
(Fig. 2A-C)

Material examined
Destra Reno: 1 spm.

Remarks

This single live collected specimen was found in a leaf litter and soil sample in Chiosco near Ancognano, in an area of oak woodland on the hills, at 265 m a.s.l. Bodon & Cianfanelli (2008) recorded this species in the Province of Bologna, but at an higher altitude along the Apennines watershed.

Distribution

Central and northern Italy, Slovenia.

Family Pomatiidae Newton, 1891
Pomatias elegans (O.F. Müller, 1774)

Material examined

Pineta di Classe: 3,513 spms, 2,696 shs; Ripristini di

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Bentivoglio: 848 spms, 351 shs; Destra Reno: 1,661 spms, 1,009 shs; Lago Brasimone: 64 spms, 45 shs.

Remarks

This species was ubiquitarian in Pineta di Classe and in Destra Reno (both on the hills and along the river). It was present in Ripristini di Bentivoglio in most sites, but not in the damper areas and marshes banks. Remarkably rare in Lago Brasimone, where it was found alive only in 15% of visual search stations and in 7% of leaf litter and soil samples. These stations are all at the south-western border of the Natura 2000 site.

Distribution

This species has a wide distribution in central and southern Europe and in northern Africa.

Family Carychiidae Jeffreys, 1830
Carychium tridentatum (Risso, 1826)
(Fig. 2D-F)

Material examined

Pineta di Classe: 18 spms, 262 shs; Ripristini di Bentivoglio: 22 spms, 290 shs; Destra Reno: 5 spms, 144 shs.

Remarks

This was an infrequent species in most sites, and absent from Lago Brasimone. It was more frequent in damper areas: live collected specimens or empty shells were found all along the Reno river, but only in 22% of the sites on the nearby hills. In Ripristini di Bentivoglio almost all specimens were found in the dampest area. In Destra Reno a specimen showing clear marks of predation was found (**Fig. 2D-F**). This type of damage conforms to "type 1" of Millar & Waite (2004) and it is expected to be caused by a predatory beetle. It is interesting to note that the predator peeled the shell for 1¾ whorls, an habit in common with some marine crabs (of which the most remarkable example is probably genus *Calappa*) when attacking gastropods (Vermeij, 1978). However, crabs usually start from the shell lip, while the predator of the *Carychium* did not break its lip. This may be the consequence of the much less resistant shell of the land snail and of the different morphology of the predator crushing apparatus. Crabs have a single mobile finger and can grab the shell by the peristome breaking it, while beetles have mandibles which are both mobile and often sharp: they can therefore more easily break the shell wall rather than the peristome, whose thickness makes it more resistant. The identification was checked by the direct observation of the parietal fold after breaking the shell wall.

Distribution

From Europe to Caucasus and northern Africa.

Family Succineidae Beck, 1837
Succinella oblonga (Draparnaud, 1801)

Material examined

Pineta di Classe: 2 shs; Ripristini di Bentivoglio: 34 shs; Destra Reno: 4 spms, 6 shs.

Remarks

This species was found both by visual search and soil sorting, but only locally: at two sites in Pineta di Classe; at two stations in Ripristini di Bentivoglio and along the Reno river. Especially at Ripristini di Bentivoglio and Destra Reno the species was associated with the more humid habitats.

Distribution

Europe and northern Asia.

Family Cochlicopidae Pilsbry, 1900
Cochlicopa lubrica (O.F. Müller, 1774)

Material examined

Pineta di Classe: 3 shs; Ripristini di Bentivoglio: 1 spm, 38 shs; Destra Reno: 3 shs.

Remarks

This species was abundant only in the most humid areas of Ripristini di Bentivoglio, where the only live collected specimen was found in a damp area at La Riccia.

Distribution

A species with a wide European distribution.

Fig. 2. A-C. *Platyla stussineri*, height 1.6 mm. **D-F**. *Carychium tridentatum* with marks of predation, height 2 mm. **G-J.** *Truncatellina* cf. *callicratis*, height 1.6 mm, Pineta di Classe. **K-N.** *Truncatellina* cf. *callicratis*, height 1.7 mm, Pineta di Classe. **O-R.** *Truncatellina* cf. *callicratis*, height 1.9 mm, Pineta di Classe. **S-V.** *Truncatellina* cf. *callicratis*, height 1.9 mm, Ripristini di Bentivoglio. **W-Z.** *Truncatellina* cf. *callicratis*, height 2.3 mm, Destra Reno. **AA-AD.** *Truncatellina* cf. *callicratis*, height 2.3 mm, Destra Reno. **AE-AH.** *Truncatellina* cf. *callicratis*, height 1.7 mm, Destra Reno. **AI-AL.** *Truncatellina* cf. *callicratis*, height 1.8 mm, Destra Reno. **AN-AO.** *Vertigo angustior*, height 1.8 mm, Pineta di Classe. **AP-AR.** *Lucilla singleyana*, diameter 3.2 mm, Destra Reno.

Fig. 2. A-C. *Platyla stussineri*, altezza 1,6 mm. **D-F**. *Carychium tridentatum* con segni di predazione, altezza 2 mm. **G-J.** *Truncatellina* cf. *callicratis*, altezza 1,6 mm, Pineta di Classe. **K-N.** *Truncatellina* cf. *callicratis*, altezza 1,7 mm, Pineta di Classe. **O-R.** *Truncatellina* cf. *callicratis*, altezza 1,9 mm, Pineta di Classe. **S-V.** *Truncatellina* cf. *callicratis*, altezza 1,9 mm, Ripristini di Bentivoglio. **W-Z.** *Truncatellina* cf. *callicratis*, altezza 2,3 mm, Destra Reno. **AA-AD.** *Truncatellina* cf. *callicratis*, altezza 2,3 mm, Destra Reno. **AE-AH.** *Truncatellina* cf. *callicratis*, altezza 1,7 mm, Destra Reno. **AI-AL.** *Truncatellina* cf. *callicratis*, altezza 1,8 mm, Destra Reno. **AN-AO.** *Vertigo angustior*, altezza 1,8 mm, Pineta di Classe. **AP-AR.** *Lucilla singleyana*, diametro 3,2 mm, Destra Reno.

Family Vertiginidae Pilsbry, 1918
Vertigo angustior Jeffreys, 1830
(Fig. 2AN, AO)

Material examined

Pineta di Classe: 75 shs; Destra Reno: 35 shs.

Remarks

The species was found by soil sorting at only two stations in Pineta di Classe and in 67% of stations in Destra Reno, exclusively along the river. It is considered a Vulnerable species in the European Red List (Cuttelod et al., 2011) and is one of the few gastropods enlisted in Annex II of the "Habitat" Directive.

Distribution

Western Eurasia to northern Iran.

Vertigo pygmaea (Draparnaud, 1801)

Material examined

Pineta di Classe: 9 shs; Destra Reno: 2 shs.

Remarks

Localized species found only in three stations in Pineta di Classe and two in Destra Reno, by sorting leaf litter and soil. It is considered a Least Concern species in the European Red List (Cuttelod et al., 2011).

Distribution

A species with a wide distribution in Europe.

Columella edentula (Draparnaud, 1805)

Material examined

Pineta di Classe: 2 spms, 9 shs.

Remarks

A localized species, found alive at a single site right in the center of the woodland and dead in four stations, by sorting leaf litter and soil. It is considered a Least Concern species in the European Red List (Cuttelod et al., 2011).

Distribution

Widespread in Europe.

Truncatellina cf. *callicratis* (Scacchi, 1833)
(Fig. 2G-AL)

Material examined

Pineta di Classe: 17 spms, 401 shs. Ripristini di Bentivoglio: 31 spms, 791 shs. Destra Reno: 9 spms, 71 shs.

Remarks

Live collected specimens or empty shells of *Truncatellina* were found everywhere in Pineta di Classe and Ripristini di Bentivoglio and in 40% of Destra Reno stations. Here live collected specimens were found more often along the river rather than on the hills. The Italian fauna has four *Truncatellina* species (Manganelli et al., 1995): *T. callicratis*, *T. claustralis* (Gredler, 1856), *T. cylindrica* (Férussac, 1807) and *T. monodon* (Held, 1837). The latter is easily recognizable by the absence of ribs and has an Alpine distribution (Welter-Schultes, 2012). *T. claustralis* has the palatal tooth deeply-set and invisible from mouth, but visible externally in rear view through the transparency of the shell as a distinct white mark (Kerney & Cameron, 1979). On the contrary, the main diagnostic shell character between *T. callicratis* and *T. cylindrica* seems to be the total absence of teeth in *T. cylindrica*, despite that tooth-less specimens can be found in *T. callicratis* too (Kerney & Cameron, 1979).
Our samples from Pineta di Classe, Ripristini di Bentivoglio and Destra Reno contained almost 1,200 specimens of *Truncatellina* displaying an astonishing morphological variation. Both shell shape and sculpture and presence/absence of teeth were considered in the attempt to discriminate between *T. cylindrica* and *T. callicratis*. However, neither of the characters mentioned above allowed us to consistently discriminate between the two. Given the frequent presence of teeth, we opted for identifying all specimens as *T. callicratis*. However, the morphological variation we observed suggested to us to reconsider the presence of teeth as a key diagnostic character in this group (supporting the hypothesis of Holyoak et al., 2012) and possibly we isolated a species group rather than a single species, hence the choice to use the "cf." notation.
It is considered a Least Concern species in the European Red List (Cuttelod et al., 2011).

Distribution

Algeria, southern Europe to central Asia.

Family Chondrinidae Steenberg, 1925
Granaria frumentum (Draparnaud, 1801)

Material examined

Pineta di Classe: 29 spms, 82 shs; Destra Reno: 13 spms, 19 shs.

Remarks

This species was intercepted alive and dead both by visual search and leaf litter and soil sorting. At Pineta di Classe it was found in half of the stations, while in Destra Reno it was found mainly on the hills (live collected specimens only). The nominal species is considered a Least Concern species in the European Red List (Cuttelod et al., 2011).

Distribution

The species *G. frumentum* (Draparnaud, 1801) is distributed from central Europe South to Italy and East to the Balkans. However, it is splitted in several subspecies. The taxon *G. frumentum illyrica* has been used for populations in Dalmatia and northern Italy so far. Recently Fehér et al. (2010) revised the distribution of these subspecies and question that *G. frumentum illyrica* is really distributed in northern Italy.

Family Lauriidae Steenberg, 1925
Lauria cyliudracea (Da Costa, 1778)

Material examined

Pineta di Classe: 1 spm.

Remarks

The single live collected specimen was found by visual search in a station with ivy at the north-western edge of the site. Remarkably, we did not find any further specimen, neither dead. It is considered a Least Concern species in the European Red List (Cuttelod et al., 2011).

Distribution

Europe to Caucasus and Arabia.

Family Argnidae Hudec, 1965
Argna biplicata (Michaud, 1831)

Material examined

Lago Brasimone: 2 shs.

Remarks

The two shells were found south of Stagno, at the south-western border of the site, in mixed deciduous woodland. It is considered a Least Concern species in the European Red List (Cuttelod et al., 2011).

Distribution

Alps and Apennines; isolated populations in Valencia (Spain) and north-western Greece.

Family Valloniidae Beck, 1847
Vallonia costata (O.F. Müller, 1774)

Material esamined

Ripristini di Bentivoglio: 7 spms, 10 shs; Destra Reno: 2 shs.

Remarks

At Ripristini di Bentivoglio the species was extremely localized in a damp area at La Riccia where all live collected specimens were found sorting soil. In Destra Reno it was found in only two stations along the river. It is considered a Least Concern species in the European Red List (Cuttelod et al., 2011).

Distribution

North Africa, Europe to central Asia.

Vallonia pulchella (O.F. Müller, 1774)

Material examined

Ripristini di Bentivoglio: 11 spms, 25 shs; Destra Reno: 2 shs.

Remarks

This species was found in Ripristini di Bentivoglio in the same area where *V. costata* was found. In Destra Reno it was found at a single station along the river. It is considered a Least Concern species in the European Red List (Cuttelod et al., 2011).

Distribution

Wide distribution in Europe.

Acauthinula aculeata (O.F. Müller, 1774)

Material examined

Destra Reno: 49 spms, 304 shs; Lago Brasimone: 17 spms, 35 shs.

Remarks

This species was found in Destra Reno both on the hills (where it was present in all the samples) and along the river (50% of stations). It was also found in 75% of stations at Lago Brasimone. It is considered a Least Concern species in the European Red List (Cuttelod et al., 2011).

Distribution

This species has a very wide distribution covering North Africa, all of Europe to Russia and Transcaucasia, the British Isles.

Family Enidae Woodward, 1903
Chondrula tridens (O.F. Müller, 1774)

Material examined

Pineta di Classe: 28 shs; Destra Reno: 1 sh.

Remarks

This species was found in 25% of stations in Pineta di

Classe, where it was found dead only and usually worn. A single worn shell was found on the hills of Destra Reno. The lack of live collected specimens may be due to the preference of this species for more open and drier habitats (Kerney & Cameron, 1979). It is considered a Near Threatened species in the European Red List (Cuttelod et al., 2011).

Distribution

A European species.

Jaminia quadridens (O.F. Müller, 1774)

Material examined

Destra Reno: 1 sh.

Remarks

A rare species found by visual search on the hills of Destra Reno, at the southernmost tip of the site. However, the species prefers more open and drier habitats than woodland (Kerney & Cameron, 1979). It is considered a Least Concern species in the European Red List (Cuttelod et al., 2011).

Distribution

A central and southern European species, ranging from Spain to Germany and northern Greece.

Merdigera obscura (O.F. Müller, 1774)

Material examined

Destra Reno: 9 shs.

Remarks

It was found in leaf litter and soil collected in more than half of the stations on the hills of Destra Reno. It is considered a Least Concern species in the European Red List (Cuttelod et al., 2011).

Distribution

Wide distribution across Europe to Uzbekistan, northwestern Africa.

Family Punctidae Morse, 1864
Punctum pygmaeum (Draparnaud, 1801)

Material examined

Pineta di Classe: 37 spms, 1401 shs; Destra Reno: 15 spms, 403 shs; Lago Brasimone: 84 spms, 274 shs.

Remarks

This species was not found in Ripristini di Bentivoglio but it was one of the most widespread and abundant species elsewhere.

Distribution

This species has a wide distribution all around Europe to West and North Asia.

Family Helicodiscidae Baker, 1927
Lucilla singleyana (Pilsbry, 1889)
(Fig. 2AP-AR)

Material examined

Destra Reno: 2 spms, 21 shs; Lago Brasimone: 3 spms, 3 shs.

Remarks

This species was found in leaf litter and soil samples in Destra Reno, mainly along the river, and in two stations at Lago Brasimone.

Distribution

This is a North American species supposed to be introduced in Europe (Welter-Schultes, 2012).

Family Discidae Thiele, 1931
Discus rotundatus (O.F. Müller, 1774)
(Fig. 3A-C)

Material examined

Pineta di Classe: 7 spms, 45 shs; Destra Reno: 5 spms; Lago Brasimone: 4 shs.

Remarks

This species was particularly abundant at Pineta di Classe, where however it was extremely localized: it was found only at two stations in the northern part of the site. Here a particularly attractive population with a

Fig. 3. A-C. *Discus rotundatus*, white colour form (broken during cleaning), diameter 4.2 mm, Pineta di Classe. **D.** *Arion* cf. *franciscoloi*, length 30 mm, Lago Brasimone. **E.** *Arion* cf. *intermedius*, length 20 mm, Lago Brasimone. **F-H.** *Aegopinella pura*, diameter 2.5 mm, Lago Brasimone. **I-K.** *Oxychilus* cf. *draparnaudi*, diameter 6.7 mm, Pineta di Classe. **L-N**. *Oxychilus* cf. *draparnaudi*, diameter 8.7 mm, Destra Reno. **O-Q.** *Oxychilus* cf. *draparnaudi*, diameter 14.1 mm, Ripristini di Bentivoglio. **R-T.** *Vitrea* cf. *etrusca*, diameter 1.4 mm, Lago Brasimone. **U-W.** *Vitrea subrimata*, diameter 2.5 mm, Lago Brasimone. **X.** *Tandonia rustica*, 20 mm, Destra Reno.

Fig. 3. A-C. *Discus rotundatus*, forma di colore bianco (rottasi durante la pulizia), diametro 4,2 mm, Pineta di Classe. **D.** *Arion* cf. *franciscoloi*, lunghezza 30 mm, Lago Brasimone. **E.** *Arion* cf. *intermedius*, lunghezza 20 mm, Lago Brasimone. **F-H.** *Aegopinella pura*, diametro 2,5 mm, Lago Brasimone. **I-K.** *Oxychilus* cf. *draparnaudi*, diametro 6,7 mm, Pineta di Classe. **L-N**. *Oxychilus* cf. *draparnaudi*, diametro 8,7 mm, Destra Reno. **O-Q.** *Oxychilus* cf. *draparnaudi*, diametro 14,1 mm, Ripristini di Bentivoglio. **R-T.** *Vitrea* cf. *etrusca*, diametro 1,4 mm, Lago Brasimone. **U-W.** *Vitrea subrimata*, diametro 2,5 mm, Lago Brasimone. **X.** *Tandonia rustica*, 20 mm, Destra Reno.

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totally white shell was found (Fig. 3A-C). In Destra Reno live collected specimens were spotted during visual search under logs.

Distribution

European species.

Family Arionidae J. Gray, 1840
Arion cf. *franciscoloi* Boato, Bodon & Giusti, 1983
(Fig. 3D)

Material examined

Lago Brasimone: 1 spm.

Remarks

The individual was found in a single station at the southeasternmost border of the site near Stagno. It was differentiated from *Arion intermedius* because of its larger size (3 cm versus 1.5 cm), darker colour, ticker skin tubercles.

Distribution

An Italian endemic, found from eastern Liguria, Toscana (only in the Alpi Apuane) and in the northern Apennines.

Arion cf. *intermedius* Normand, 1852
(Fig. 3E)

Material examined

Lago Brasimone: 4 spms.

Remarks

The four live collected specimens were found in two stations close to each other, in the beech woodland on the right of the stream Brasimone.

Distribution

An European species.

Family Oxychilidae Hesse in Geyer, 1927
Aegopinella pura (Alder, 1830)
(Fig. 3F-H)

Material examined

Lago Brasimone: 1 sh.

Remarks

A very rare species: a single dead but fresh specimen was found in leaf litter and soil at a single site near the spring of the Brasimone stream, in beech woodland at 1,131 m a.s.l., at the southernmost tip of the site of Lago Brasimone, very close to the watershed and the border with Toscana.

Distribution

An European species, occurring East to Iran.

Oxychilus cf. *draparnaudi* (H. Beck, 1837)
(Fig. 3I-Q)

Material esamined

Pineta di Classe: 82 shs; Ripristini di Bentivoglio: 2 spms, 88 shs; Destra Reno: 2 spms, 4 shs.

Remarks

This species was ubiquitarian in Pineta di Classe and Ripristini di Bentivoglio, while rare in Destra Reno. It was not found at Lago Brasimone. The species was intercepted mostly by leaf litter and soil sorting. However, visual search was particularly effective in Ripristini di Bentivoglio and the only collecting method who allowed the finding of the few specimens of Destra Reno. *Oxychilus* species can be unambiguously identified only when soft parts are available for the analysis of the reproductive apparatus. For this reason, we chose the "cf." notation being aware that our identification on the shell morphology might not be definitive and that we may have lumped more species in a single entity.

Distribution

Original distribution in south-western and western Europe, but nowadays worldwide dispersed.

Retinella olivetorum (Gmelin, 1791)

Material examined

Destra Reno: 60 spms, 423 shs; Lago Brasimone: 2 shs.

Remarks

This species was particularly frequent in Destra Reno, where it was found in 75% of stations on the hills, and 63% of stations along the river.

Distribution

This is a species distributed in Italy and with a relict population in southern France (Magnin et al., 2012).

Family Pristilomatidae T. Cockerell, 1891
Vitrea cf. *etrusca* (Paulucci, 1878)
(Fig. 3R-T)

Material examined

Lago Brasimone: 4 shs.

Remarks

The specimens attributed to this species were found in a single sample of leaf litter and soil collected at the south-westernmost border of the site near Chiapporato, in mixed deciduous woodland.

Distribution

This is a species endemic to Italy and Corsica.

Vitrea subrimata (Reinhardt, 1871)
(Fig. 3U-W)

Material examined

Pineta di Classe: 11 spms, 338 shs; Destra Reno: 23 spms, 90 shs; Lago Brasimone: 69 spms, 116 shs.

Remarks

This was a frequent species in leaf litter and soil samples, found in 75% of stations at Pineta di Classe, in 47% of stations in Destra Reno (but 67% in the hills), and 93% of stations at Lago Brasimone.

Distribution

Central and southern Europe, North Africa.

Family Milacidae Ellis, 1926
Tandouia rustica (Millet, 1843)
(Fig. 3X)

Material examined

Destra Reno: 1 spm.

Remarks

A single individual was found in oak woodland at 131 m a.s.l., near Le Ganzole at the southernmost tip of the site Destra Reno.

Distribution

Central and southern Europe.

Family Limacidae Rafinesque, 1815
Limax sp.
(Fig. 4A, B)

Material examined

Destra Reno: 7 spms; Lago Brasimone: 22 spms.

Remarks

This *Limax* was found in half of the stations in Destra Reno along the river and in half of sites at Lago Brasimone. A large species exceeding 20 cm when extended.

Family Agriolimacidae H. Wagner, 1935
Deroceras cf. *reticulatum* (O.F. Müller, 1774)
(Fig. 4C)

Material esamined

Pineta di Classe: 3 spms; Ripristini di Bentivoglio: 16 spms; Destra Reno: 17 spms.

Remarks

This species was found only locally at low altitude. At Ripristini di Bentivoglio it was found in two stations only near La Riccia, while in Destra Reno only in three stations along the river. It was not found in the forests of Lago Brasimone.

Distribution

Wide European distribution, now introduced worldwide.

Family Euconulidae Baker, 1928
Euconulus fulvus (O.F. Müller, 1774)

Material examined

Ripristini di Bentivoglio: 6 shs; Destra Reno: 9 spms, 21 shs.

Remarks

It was found in a damp area at La Riccia in Ripristini di Bentivoglio and in Destra Reno only along the river.

Distribution

Northern Hemisphere.

Family Ferrussaciidae Bourguignat, 1883
Cecilioides acicula (O.F. Müller, 1774)

Material esamined

Ripristini di Bentivoglio: 20 shs; Destra Reno: 4 spms, 39 shs.

Remarks

This species was rather frequent in Ripristini di Bentivoglio, shells were found in 80% of sampling sites. In Destra Reno it was easier to find along the river than on the hills. It was remarkably easier to find empty shells and this may be a consequence of the subterranean living habit of the species (Kerney & Cameron, 1979).

Distribution

Europe to central Asia and northern Africa.

Fig. 4. A-B. *Limax* sp., length 110 mm, Lago Brasimone. **C**. *Deroceras* cf. *reticulatum*, length 30 mm, Pineta di Classe. **D.** *Testacella scutulum*, length 20 mm, Destra Reno. **E.** *Testacella scutulum*, length 20 mm, Lago Brasimone. **F-H.** *Testacella scutulum*, height 1.75 mm, Destra Reno. **I-K**. *Candidula* cf. *unifasciata*, diameter 6.4 mm, Destra Reno. **L-N.** *Helix lucorum*, uniform light grey colour form, diameter 36.3, Ripristini di Bentivoglio.

Fig. 4. A-B. *Limax* sp., lunghezza 110 mm, Lago Brasimone. **C**. *Deroceras* cf. *reticulatum*, lunghezza 30 mm, Pineta di Classe. **D.** *Testacella scutulum*, lunghezza 20 mm, Destra Reno. **E.** *Testacella scutulum*, lunghezza 20 mm, Lago Brasimone. **F-H.** *Testacella scutulum*, altezza 1,75 mm, Destra Reno. **I-K**. *Candidula* cf. *unifasciata*, diametro 6,4 mm, Destra Reno. **L-N.** *Helix lucorum*, individuo di colore uniforme grigio chiaro, diametro 36,3 mm, Ripristini di Bentivoglio.

Family Subulinidae P. Fischer & Crosse, 1877
Rumina decollata (Linnaeus, 1758)

Material esamined

Pineta di Classe: 20 spms, 76 shs; Ripristini di Bentivoglio: 2 spms, 45 shs; Destra Reno: 9 shs.

Remarks

Live collected specimens in Pineta di Classe were often observed buried in the soil. It was found in the drier parts of the sites and was totally absent from the stations along the river Reno. Moreover, in Destra Reno it was found only at its northern tip, in the most disturbed parts of the oak woodlands, which is an area much frequented by people and close to buildings.

Distribution

Southern Europe and northern Africa.

Family Testacellidae Draparnaud, 1801
Testacella scutulum G.B. Sowerby I, 1820
(Fig. 4D-H)

Material examined

Destra Reno: 1 spm, 12 shs; Lago Brasimone: 2 spms.

Remarks

A rare species, possibly poorly intercepted alive because of its subterranean living habit (Kerney & Cameron, 1979). Indeed, empty shells were found much more often in Destra Reno (40% of soil samples, while it was found alive in a single station). At Lago Brasimone it was very localized: the two live collected specimens were found in a single station.

Distribution

An European species.

Family Clausiliidae Mörch, 1864
Cochlodina comensis (Pfeiffer, 1850)
(Fig. 5A-D)

Material examined

Destra Reno: 11 spms, 1 sh; Lago Brasimone: 4 spms, 4 shs.

Remarks

As for most of the clausiliids cited below, visual search proved to be much more effective than leaf litter and soil sorting for interception. In Destra Reno, only found along the river.

Distribution

Alps and northern Apennines.

Cochlodina laminata (Montagu, 1803)
(Fig. 5E-H)

Material examined

Destra Reno: 18 spms; Lago Brasimone: 17 spms, 2 shs.

Remarks

This species was found alive under dead wood in stations along the Reno river and in a few stations at Lago Brasimone. In Destra Reno, where it was found only along the river, it was observed exploiting holes in dead wood made by insect larvae as a humid refuge in exposed places.

Distribution

Europe and Caucasus.

Macrogastra attenuata (Rossmässler, 1835)
(Fig. 5Q-T)

Material examined

Destra Reno: 24 spms; Lago Brasimone: 2 spms.

Remarks

This species was found alive under dead wood.

Distribution

A central European species.

Macrogastra plicatula (Draparnaud, 1801)
(Fig. 5U-X)

Material examined

Lago Brasimone: 6 spms, 1 sh.

Remarks

A rare species found only at two stations. It was found only at Lago Brasimone. On the basis of lithology (arenaceous-pelitic rocks), this is the site with the most acidic soil. Other authors reported this species avoids low pH sites (Wäreborn, 1982).

Distribution

An European species.

Clausilia cruciata (S. Studer, 1820)
(Fig. 5M-P)

Fig. 5. **A-D** *Cochlodina comensis*, height 12.3 mm. **E-H**. *Cochlodina laminata*, height 17.2 mm. **I-L**. *Bulgarica denticulata*, height 14.5 mm, Pineta di Classe. **M-P.** *Clausilia cruciata*, height 11.6 mm, Destra Reno. **Q-T.** *Macrogastra attenuata*, height 15 mm. **U-X**. *Macrogastra plicatula*, height 12.7 mm, Lago Brasimone.

Fig. 5. A-D. *Cochlodina comensis*, altezza 12,3 mm. **E-H**. *Cochlodina laminata*, altezza 17,2 mm. **I-L**. *Bulgarica denticulata*, altezza 14,5 mm, Pineta di Classe. **M-P.** *Clausilia cruciata*, altezza 11,6 mm, Destra Reno. **Q-T.** *Macrogastra attenuata*, altezza 15 mm. **U-X**. *Macrogastra plicatula*, altezza 12,7 mm, Lago Brasimone.

Material examined

Destra Reno: 5 spms, 3 shs; Lago Brasimone: 7 spms.

Remarks

This clausiliid was found both along the river and in the woodland on the hills in Destra Reno, and both in the mixed deciduous forest and in the beech forest at Lago Brasimone.

Distribution

An European species.

Bulgarica denticulata (Olivier, 1801)
(Fig. 5I-L)

Material examined

Pineta di Classe: 473 spms, 503 shs.

Remarks

This species was found alive almost everywhere in the site of Pineta di Classe. It was intercepted alive both with visual search (90% of stations) and leaf litter and soil sorting (60% of stations). If also empty shells are considered, the species was ubiquitarian. The species was easily observable during our day light sampling in exposed places, like on bark and trunks, and also among dead leaves.

Distribution

In Italy it is an alien species, whose original distribution is south-eastern Europe and western Turkey (see Discussion).

Family Hygromiidae Tryon, 1866
Xerotricha conspurcata (Draparnaud, 1801)

Material examined

Ripristini di Bentivoglio: 41 spms, 44 shs; Destra Reno: 2 shs.

Remarks

This species was found alive at a single station at Ripristini di Bentivoglio, where it was found by visual search under fallen tree branches. It is considered a Least Concern species in the European Red List (Cuttelod et al., 2011).

Distribution

A southern European species.

Candidula cf. *unifasciata* (Poiret, 1801)
(Fig. 4I-K)

Material examined

Destra Reno: 1 spm, 62 shs.

Remarks

This species was found mainly on the hills of Destra Reno, sorting leaf litter and soil. Notwithstanding the several empty shells found, only a single live collected specimen was collected. This may be due to the species preference for dry open places (Kerney & Cameron, 1979) rather than the forested habitats targeted by our research. It is considered a Least Concern species in the European Red List (Cuttelod et al., 2011).

Distribution

A central European species.

Hygromia cinctella (Draparnaud, 1801)

Material examined

Pineta di Classe: 18 spms, 121 shs; Ripristini di Bentivoglio: 2 spms, 101 shs; Destra Reno: 8 spms, 39 shs; Lago Brasimone: 2 shs.

Remarks

This was a common species throughout our survey with the only exception of Lago Brasimone where only 2 very worn specimens were found. It was found often alive on or under the leaves of plants. It is considered a Least Concern species in the European Red List (Cuttelod et al., 2011).

Distribution

Central and southern Europe.

Cernuella cisalpina (Rossmässler, 1837)

Material examined

Pineta di Classe: 243 shs; Ripristini di Bentivoglio: 138 shs; Destra Reno: 9 shs.

Remarks

Remarkably, we were not able to intercept live collected specimens in our quantitative samples, notwithstanding the high number of empty shells found. As for *Candidula* cf. *unifasciata*, the species may prefer more open habitats than woodland. It is also tolerant to ruderal habitats and a few living specimens were found within the woodland near buildings. It is considered a Least Concern species in the European Red List (Cuttelod et al., 2011).

Distribution

A southern European species.

Cernuella neglecta (Draparnaud, 1805)

Material esamined

Pineta di Classe: 1 spm, 87 shs; Ripristini di Bentivoglio: 13 shs.

Remarks

As for other hygromiids, we found several empty shells but a single live collected specimen, possibly because of their preference for drier and more open habitat than woodland (Kerney & Cameron, 1979). It is considered a Least Concern species in the European Red List (Cuttelod et al., 2011).

Distribution

An European species.

Ciliella ciliata (W. Hartmann, 1821)

Material examined

Lago Brasimone: 1 sh.

Remarks

A single specimen was found on the western border of the site, in mixed deciduous woodland with oak, hornbeam and chestnut. Giusti et al. (1985) reported it as a very rare species in Italian forests. It is considered a Least Concern species in the European Red List (Cuttelod et al., 2011).

Distribution

From the eastern Pyrenees to Alps and the Apennines.

Trochoidea trochoides (Poiret, 1789)

Material examined

Pineta di Classe: 25 shs.

Remarks

This species was found in almost half of the stations, but always dead and worn. It is considered a Least Concern species in the European Red List (Cuttelod et al., 2011).

Distribution

A coastal western Mediterranean species.

Monacha cantiana (Montagu, 1803)

Material esamined

Pineta di Classe: 1 spm, 75 shs; Ripristini di Bentivoglio: 2 spms, 472 shs; Destra Reno: 83 spms, 55 shs.

Remarks

This species was particularly common in Destra Reno, where several live collected specimens were found in woodland. The species was widespread as most stations along the river (88%) and on hills (42%) had it. It was usually found on vegetation. It is considered a Least Concern species in the European Red List (Cuttelod et al., 2011).

Distribution

Originally Italy and southern France, but introduced to central Europe and the British Isles.

Monacha cartusiana (O.F. Müller, 1774)

Material esamined

Pineta di Classe: 3 shs; Ripristini di Bentivoglio: 4 shs; Destra Reno: 2 shs.

Remarks

This was apparently a rare species in our survey. However, while we are reasonably confident about the identification of adult *Monacha*, the identification of the many juvenile and often worn empty shells found in the leaf litter and soil samples proved very difficult. We can't exclude that the frequency and abundance of this species was underestimated due to misidentification of such specimens with *M. cantiana*. It is considered a Least Concern species in the European Red List (Cuttelod et al., 2011).

Distribution

Wide European distribution from Portugal to Ukraine.

Family Cochlicellidae Schileyko, 1972

Cochlicella acuta (O.F. Müller, 1774)

Material examined

Pineta di Classe: 12 shs.

Remarks

This is a typical maritime species and indeed it was found in Pineta di Classe only. The absence of live collected specimens from our quantitative samples in woodland may be due to the preference of the species for more open and drier habitats (Kerney & Cameron, 1979). Live collected specimens were collected outside the stations after rain near the visitors centre of the reserve. It is considered a Least Concern species in the European Red List (Cuttelod et al., 2011).

Distribution

Coasts of the British Isles, western Europe, Mediterra-

nean coasts of Europe and then eastward to the Middle East.

Family Helicodontidae Kobelt, 1904
Helicodonta obvoluta (O.F. Müller, 1774)

Material examined

Destra Reno: 23 spms, 68 shs; Lago Brasimone: 7 spms, 18 shs.

Remarks

This species was rather frequent in Destra Reno where it was found in 55% of stations (along the river and on the hills alike). It was also present in 50% of stations at Lago Brasimone. It is considered a Least Concern species in the European Red List (Cuttelod et al., 2011).

Distribution

An European species.

Family Helicidae Rafinesque, 1815
Chilostoma planospira (Lamarck, 1822)

Material examined

Lago Brasimone: 4 shs.

Remarks

The few empty shells were found in stations spread over the site. A living specimen was observed outside stations near Bagno. It is considered a Data Deficient species in the European Red List (Cuttelod et al., 2011).

Distribution

This is a species endemic to Italy.

Eobania vermiculata (O.F. Müller, 1774)

Material examined

Destra Reno: 2 shs.

Remarks

This species was found at a single station on the hills of Destra Reno: Monte Belvedere. It is considered a Least Concern species in the European Red List (Cuttelod et al., 2011).

Distribution

A species originally found in southern Europe, but now introduced to many other countries.

Cepaea nemoralis (Linnaeus, 1758)

Material esamined

Pineta di Classe: 1 spm, 88 shs; Ripristini di Bentivoglio: 12 spms, 265 shs; Destra Reno: 2 spms, 7 shs; Lago Brasimone: 1 sh.

Remarks

At Ripristini di Bentivoglio, this species was found alive or dead in all samples. However, live collected specimens were rare, notwithstanding the abundance of empty shells. It was also rather frequent at Pineta di Classe, where it was present in 60% of sampling sites. In Destra Reno it was found only along the river where the few specimens found were spread over most stations (63%). The only specimen found at Lago Brasimone had an attractive salmon pink pattern. It is considered a Least Concern species in the European Red List (Cuttelod et al., 2011).

Distribution

An European species.

Cornu aspersum (O.F. Müller, 1774)

Material examined

Pineta di Classe: 3 spms, 22 shs; Ripristini di Bentivoglio: 7 shs.

Remarks

The species was found in 55% and 40% respectively of the stations of Pineta di Classe and Ripristini di Bentivoglio, despite that live collected specimens were rarely encountered. It is considered a Least Concern species in the European Red List (Cuttelod et al., 2011).

Distribution

Originally a species spread around the Mediterranean Sea, but now introduced worldwide.

Helix cincta O.F. Müller, 1774

Material examined

Pineta di Classe: 5 spms, 20 shs; Destra Reno: 22 shs.

Remarks

At Pineta di Classe the species was extremely localized: specimens were found only at two stations in its northernmost part. In Destra Reno the species was found only on the hills, but quite widespread along the site. It is considered a Least Concern species in the European Red List (Cuttelod et al., 2011).

Distribution

A southern European species ranging from northern Italy to Turkey and Lebanon.

Helix lucorum Linnaeus, 1758
(Fig. 4L-N)

Material examined

Pineta di Classe: 12 shs; Ripristini di Bentivoglio: 627 spms, 1099 shs; Destra Reno: 1 spm, 120 shs.

Remarks

This species was incredibly abundant in Ripristini di Bentivoglio, where at some sites it was necessary to be extremely careful when walking to avoid stepping on specimens. At this site an unusual colour variation was found (Fig. 4G-I): the shell was uniformly light grey, but no differences could be noticed in the colour pattern of the animal. It is considered a Least Concern species in the European Red List (Cuttelod et al., 2011).

Distribution

A species found from southern Europe to the Middle East.

Discussion

Comparison with the Italian fauna and other local faunas

The 58 species here found are approximately 11% of the Italian land mollusc fauna (Manganelli et al., 2000) and 48% of the fauna of Emilia-Romagna (preliminary unpublished checklist by the Authors). Of the 57 species which were identified at the species level, 46 (80.7%) are characterized by a wide distribution in Europe, while 7 (12.3%) have a distribution restricted to one to few countries. Among these, four species have a distribution mostly restricted to Italy or are Italian endemics: *Arion* cf. *franciscoloi*, endemic to area from eastern Liguria to the northern Apennines, *Retinella olivetorum*, distributed all along the Italian peninsula and in a relict area in southern France; *Vitrea etrusca*, with a distribution restricted to northern and Central Italy and Corsica; *Chilostoma planospira*, distributed along most of Italy. Most of the species found (39, 68.4%) have a distribution which covers central Europe, while the remaining 18 (31.6%) are restricted to southern Europe.

These figures are typical of the fauna of Emilia-Romagna. Palazzi (1985) described the fauna of the province of Modena cumulating data from personal collecting and the literature. This province neighbours the province of Bologna on its western side and shares with it a similar altitudinal excursion ranging from ≈2000 m a.s.l. to lowland near the river Po. After a few taxonomical emendations, his work listed 72 species, sharing almost 60% of the species with our findings and maintaining the same strong continental affinity. This figure may rise up to 68% if the identification of a few species could be better reconciled with the modern nomenclature we followed. Among the species cited by Palazzi we did not find, there are some species with a southern France-north-western Italy distribution which might find in the Province of Modena their easternmost distribution in Emilia-Romagna like *Granaria variabilis* (Draparnaud, 1801), *Solatopupa similis* (Bruguiere, 1792) and *Itala itala* (von Martens, 1824) and some other rare species, like *Renea elegantissima* (Pini, 1886) and *Vertigo moulinsiana* (Dupuy, 1849). Most other species have a wide distribution in Italy and Europe and could possibly also be part of the fauna of the provinces we investigated rising even more the degree of similarity between the two territories.

Zangheri (1969) described the fauna of Romagna, neighbouring the province of Bologna on the East and including the site "Pineta di Classe". After clearing evident misidentifications and updating the nomenclature, again a significant overlap with our study could be noticed: 58.5% of the species are in common between the two lists, and up to 64.6% if the identification of a few species could be again better reconciled with the modern nomenclature we followed. Among the other species Zangheri cited, some are southern species which find their northern range limit in Romagna, like *Semilimacella bonelli* (Targioni Tozzetti, 1873), *Tandonia sowerbyi* (Férussac, 1823), *Ferussacia folliculus* (Schröter, 1784), *Siciliaria gibbula* (Rossmässler, 1836), *Papillifera bidens* (Linnaeus, 1758), *Monacha martensiana* (Tiberi, 1869) and *Theba pisana* (O.F. Müller, 1774). Some of them do not live in coastal pine woodlands, and hence their absence in our survey. Most other species we did not find have a wider European or Mediterranean distribution and could well be found in the territories we surveyed if a wider range of habitat would have been investigated, again rising even more the degree of similarity between our study sites and Romagna.

Conservation interest

The conservation status of 30 of the 63 species found (47.6%) was evaluated in the European Red-List of non-marine molluscs (Cuttelod et al., 2011). A single species, *Chilostoma planospira*, was considered Data Deficient (DD). Most species (27, 42.9% of the whole fauna) were listed as Least Concern, while *Chondrula tridens* was the only species being listed as Near Threatened (NT). A single threatened species was found: *Vertigo angustior*, which was listed as Vulnerable (VU). *Vertigo angustior* is also listed among the species in need of designation of special areas of conservation (Annex II) in the "Habitat" Directive. However, in Italy the species seems to have a better conservation status (Manganelli et al., 2000).

Arrival of the alien species *Bulgarica denticulata*

The history of the presence of *Bulgarica denticulata* in Romagna is complicated by an articulated nomenclatural history. The species was listed as *Bulgarica thessalonica* (Rossmässler, 1839) in the Checklist of Italian Fau-

na (Manganelli et al., 1995). Zangheri (1969) listed the species as *Laciniaria plicata* (Draparnaud, 1801) and a nice illustration of specimens from Romagna was provided by Lazzari (2007) under this name.

Zangheri's record suggests that the species is present in the area at least since the mid 20th century. However, Tassinari (1854) recorded *Clausilia semidenticulata* Pfeiffer, a taxon now considered a synonym of *Bulgarica denticulata*, from the Ravenna pine woodlands. He already described it as an alien: he recorded the species from the pine woodlands of Ravenna and specified that *"Sinora non era stata rinvenuta che nell'Asia minore, donde forse venne trasportata a Ravenna colle navi durante la sua dipendenza dall'Impero d'Oriente"* [to date, the species has been found only in Turkey. Probably it was brought to Ravenna by ships during the Byzantine Empire]. The same hypothesis was proposed in recent times in a review of the modes of introduction of continental molluscs to Italy (Hallgass & Vannozzi, 2010). Despite that this is a plausible explanation of the introduction of the species to Italy, it is interesting to note that in the 18th century Ginanni (1757) did not record anything similar. The work by Ginanni is prelinnean, so it is not straightforward to recognize modern taxa in there. However, *Bulgarica denticulata* is a sinistral species, an easy character to trace even in ancient works with poorly detailed illustrations of small sized species like Ginanni's one. The only sinistral species illustrated in the plates is on plate III of the land snail section, figure 23 (**Fig. 6**). The figure does show sinistrality, but obliterates any further diagnostic character. The figure corresponds to *"turbine terrestre minore"* as described on page 59. The diagnosis is however quite clear in describing something different than *Bulgarica denticulata*: *"di color terreo, che ha nove giri nella voluta, e nell'unione di ciascuno di essi è sparso di piccole tuberosità bianchiccie, che fanno dentati i giri medesimi. Il primo di questi, che forma la bocca, e si dilata un poco a foggia di tromba, è contornato da un labbretto bianco, e tutti sono rigati orizzontalmente. L'ho ritrovato negli Orti di Ravenna, che sono circondati di muri."* [brown, with 9 whorls, sutures with small white tubercles; due to these tubercles, the appearance of the whorls is denticulate. The aperture is slightly inflated and with a white border. All the whorls are longitudinally striated. Found in gardens surrounded by walls in Ravenna]. The reference to the white subsutural protuberances suggests this to be *Papillifera bidens* (Linnaeus, 1758) rather than *Bulgarica denticulata*. More than 30 years later, a major work by Ginanni on the social and natural history of the pine woodlands of Ravenna was published posthumously (Ginanni, 1774). In the section on molluscs there is often reference to the work of 1757. However, there is no record of the *"turbine terrestre minore"* nor of any other species which might resemble a clausiliid. Today, *Bulgarica denticulata* is a highly frequent and abundant species in the pine woodlands of Ravenna. If the colonization has to be dated back to the Byzantine Empire, it can be hypothesized that the species in the 18th century had already had enough time to spread and form consistent populations similar to the ones we see today. In this perspective, the lack of any reference to a similar species in Ginanni's works is compelling. Despite that the evidences collected in the ancient literature cannot be considered conclusive on the date of colonization of Ravenna's pine woodlands by the species, we suggest that its colonization might have been more recent that considered to date, and datable between the end of the 18th century and the beginning of the 19th century.

Fig. 6. *"Turbine terrestre minore"*, the only sinistral shell referable to a clausiliid reported by Ginanni (1757). It is probably *Papillifera bidens*, as its description suggests.

Fig. 6. "Turbine terrestre minore", l'unica conchiglia sinistrorsa riferibile ad un clausiliide riportata da Ginanni (1757). Si tratta probabilmente di *Papillifera bidens*, come suggerito dalla descrizione.

Conclusions

This is one of the few faunistic works dealing with the land snail fauna of Emilia-Romagna region. The choice of sites along an altitudinal transect and with different forested habitats contributed to increase the diversity we managed to intercept. Fifty-eight species are here recorded, they represent approximately 11% of the Italian land snail fauna and 48% of the estimated fauna of Emilia-Romagna. Our study evidenced the presence of a vulnerable species, *Vertigo angustior*, and of a near threatened one, *Chondrula tridens*. Moreover, the alien species *Bulgarica denticulata* was found widely distributed in the coastal site of Pineta di Classe, near Ravenna. On the basis of the ancient literature, we hypothesize that the settlement of this species in the area is more recent than previously considered, and may be dated between the end of the 18th century and the beginning of the 19th century.

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Data di pubblicazione del "Catalogo sistematico e ragionato de' testacei delle Due Sicilie" di O.G. Costa

Giuseppe Fasulo*

*Via G. Merliani 20,
80127 Napoli, Italia,
fasulogiuseppe@hotmail.it

Riassunto
L'anno di pubblicazione del "Catalogo sistematico e ragionato de' testacei delle Due Sicilie" di O.G. Costa è il 1830, e non il 1829.

Parole chiave
O.G. Costa, bibliografia, data di pubblicazione.

Abstract
The publication date of O.G. Costa's "Catalogo sistematico e ragionato de' testacei delle Due Sicilie" is 1830, rather than the imprint date of 1829, since both dedication letter by Costa and gratitude message by Marquess Giuseppe Ruffo are dated november 1830.

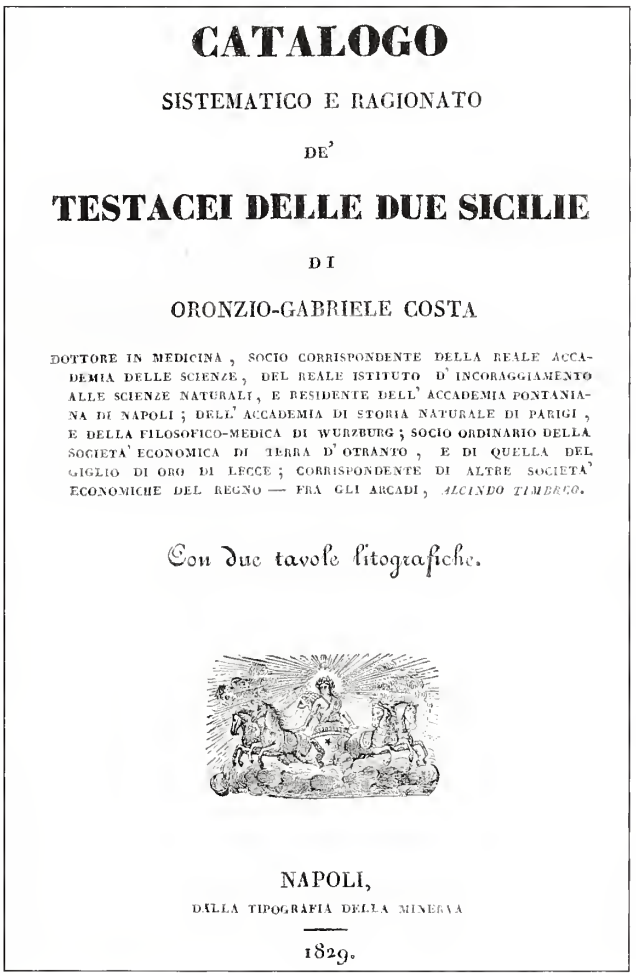
Key words
O.G. Costa, bibliography, publication date.

Introduzione

Il "Catalogo sistematico e ragionato de' testacei delle Due Sicilie" è un'opera classica di malacologia mediterranea di Oronzio Gabriele Costa (1787-1867), nella quale furono descritti diversi nuovi taxa. L'anno di pubblicazione finora attribuito all'opera è il 1829, data che compare sul frontespizio dell'opera (**Fig. 1**).

Discussione

Le prime due pagine dell'opera riportano la dedica dell'autore al marchese Giuseppe Ruffo, ministro della casa Reale Borbonica, che è datata "23 novembre 1830", a cui segue una breve frase di riconoscenza da parte del Ruffo, riportante la data del "24 novembre 1830" (**Fig. 2A, B**). La pubblicazione dell'opera non può quindi essere anteriore alle due predette date (novembre 1830) ed il "Catalogo" si deve considerare pubblicato il 31 dicembre 1830 (ICZN, 1999: Art. 21.3).
La data di pubblicazione di questa opera fu riportata come 1829 da Sherborn (1922: p. XXXIX), anche se accompagnata dalla dicitura "[Pref. dated 1830]". Nessun riferimento a questa opera di Costa si trova invece in Sherborn (1937).
Pertanto, la data di pubblicazione dei nuovi taxa di molluschi istituiti dal Costa nell'opera in esame, qui elencati assieme alla nomenclatura aggiornata, va intesa come 1830 e non 1829, come finora riportato.
Va rimarcato che la nuova data di pubblicazione non comporta cambiamenti nella nomenclatura, a parte l'anno di pubblicazione, dei taxa coinvolti (**Tab. 1**).
I taxa *Emarginula elongata* (= *Emarginula octaviana* Coen,



CATALOGO

SISTEMATICO E RAGIONATO

DE'

TESTACEI DELLE DUE SICILIE

DI

ORONZIO-GABRIELE COSTA

DOTTORE IN MEDICINA, SOCIO CORRISPONDENTE DELLA REALE ACCADEMIA DELLE SCIENZE, DEL REALE ISTITUTO D' INCORAGGIAMENTO ALLE SCIENZE NATURALI, E RESIDENTE DELL' ACCADEMIA PONTANIANA DI NAPOLI; DELL' ACCADEMIA DI STORIA NATURALE DI PARIGI, E DELLA FILOSOFICO-MEDICA DI WURZBURG; SOCIO ORDINARIO DELLA SOCIETA' ECONOMICA DI TERRA D' OTRANTO, E DI QUELLA DEL GIGLIO DI ORO DI LECCE; CORRISPONDENTE DI ALTRE SOCIETA' ECONOMICHE DEL REGNO — FRA GLI ARCADI, *ALCINDO TIMBREO*.

Con due tavole litografiche.

NAPOLI,
DALLA TIPOGRAFIA DELLA MINERVA
1829.

Fig. 1. Frotenspizio del "Catalogo sistematico e ragionato de' testacei delle Due Sicilie", con la data di pubblicazione "1829".

Fig. 1. Frontispiece of "Catalogo sistematico e ragionato de' testacei delle Due Sicilie", with the publication date "1829".

A S. E.

SIGNOR MARCHESE

D. GIUSEPPE RUFFO

DIRETTORE DEL MINISTERO E REAL SEGRETERIA DI STATO DI CASA REALE E DEGLI ORDINI CAVALLERESCHI, GRAN CROCE DEL R. ORDINE DI FRANCESCO I.°, MAGGIORDOMO DI SETTIMANA E GENTILUOMO DI CAMERA DI S. M. (D. G.), GRAN CROCE DEL R. ORDINE COSTANTINIANO, COMMENDATORE DEL REAL ORDINE DELLA LEGION D'ONORE, SOCIO ORDINARIO DELLA REALE ACCADEMIA DELLE SCIENZE DI NAPOLI, ecc. ecc. ecc.

ECCELLENZA.

Non i chiari titoli che la decorano, mi chiamano ad offrirle in omaggio questo tenue lavoro, perciocchè è tributo necessario e dettato da sentimenti più leali e più semplici. Le qualità personali che la distinguono, tanto nella repubblica letteraria, quanto nel disimpegno della sua carica; la protezione che concede agli uomini di lettere ed agli scienzati d' ogni classe; la beneficenza che esercita verso coloro che gliene schiudono il bisogno, son titoli assai eminenti che richiamano l' attenzione di chi ha la sorte di conoscerla. A questi si aggiungono in me particolari sentimenti di gratitudine e di amicizia, dai quali obbligato mi sento a retribuirle questo picciolo, ma pubblico contrassegno di divozione: e la scongiuro, SIGNORE, a volerlo accogliere ancora a questi soli titoli, in difetto dei meriti di che l' opera manca.

Sono dell' E. V.

Napoli 23 *Novembre* 1830.

Napoli 24 Novembre 1830.

L' accetto con riconoscenza

MARCHESE GIUSEPPE RUFFO.

Divotiss., ed Obblig. Serv. ed Amico

ORONZIO-GABRIELE COSTA.

Fig. 2. Pagine 1 e 2, contenenti la dedica di O.G. Costa al Marchese G. Ruffo (con la data del 23 Novembre 1830), ed un breve messaggio di gratitudine a Costa da parte di Ruffo (con la data del 24 Novembre 1830).

Fig. 2. Pages 1 and 2, reporting the dedication letter by O.G. Costa to Marquess G. Ruffo (dated 23 November 1830), and a brief gratitude message by Ruffo to Costa (dated 24 November 2030).

Chiton rubicundus	*Chiton corallinus* (Risso, 1826)	
Chiton euplaeae	*Callochiton septemvalvis* (Montagu, 1803)	1
Chiton stigma	*Callochiton septemvalvis* (Montagu, 1803)	2
Psammobia cumana	***Macoma cumana* (O.G. Costa, 1830)**	
Psammotaea striata	*Abra prismatica* (Montagu, 1803)	
Odoncineta	*Thracia* Leach in Blainville, 1824	
Peronea textilis	*Thracia phaseolina* (Lamarck, 1818)	3
Corbula mediterranea	***Lentidium mediterraneum* (O.G. Costa, 1830)**	
Corbula olimpica	*Corbula gibba* (Olivi, 1792)	
Venus petagnae	*Astarte fusca* (Poli, 1791)	
Venus tenorii	*Venerupis corrugata* (Gmelin, 1791)	
Spondylus gussonii	***Spondylus gussonii* O.G. Costa, 1830**	
Argonauta uniumbilicatus	*Scissurella costata* d'Orbigny, 1824	
Cypraea umbilicalis	*Trivia arctica* (Pulteney, 1799)	4.
Voluta oryza	*Ringicula auriculata* (Ménard de la Groye, 1811)	
Buccinum elegans	*Nassarius cuvierii* (Payraudeau, 1826)	
Buccinum semiplicatum	*Nassarius corniculum* (Olivi, 1792),	4
Cerithium inversus	? *Monophorus perversus* (Linneo, 1758)	4
Turbinella eburnea	*Pollia dorbignyi* (Payraudeau, 1826)	
Trochus varians	*Gibbula divaricata* (Linneo, 1758)	5
Trochus lineolatus	*Gibbula divaricata* (Linneo, 1758);	
Helix crispata	*Cornu mazzullii* (De Cristofori & Jan, 1832)	4
Janthina bicolor	*Janthina janthina* (Linneo, 1758) non *Janthina bicolor* Menke, 1828	
Pupa splendidula	*Ferussacia folliculus* (Gmelin, 1791)	5
Emarginula adriatica	***Emarginula adriatica* O.G. Costa, 1830**	
Dentalium splendens	*Fustiaria rubescen* (Deshayes, 1825)	6
Cyclas sebetia	***Bornia sebetia* (O.G. Costa, 1830)**	

Tab. 1. Elenco dei nuovi taxa introdotti da Costa (1830). Nella prima colonna è riportato il nome originale del taxon, nella seconda l'aggiornamento nomenclaturale (in grassetto i taxa validi). Note: 1. Dell'Angelo & Palazzi (1994); 2. Monterosato (1879); 3. Taxon introdotto per le parti molli del mollusco; 4. Philippi (1836); 5. Scacchi (1836); 6. Pilsbry & Sharp (1897).

Tab. 1. New taxa introduced by Costa (1830), with original names (first column) and nomenclatural update (second column). Valid taxa are in boldface. Notes: 1. Dell'Angelo & Palazzi (1994); 2. Monterosato (1879); 3. Taxon introduced for the soft parts only; 4. Philippi (1836); 5. Scacchi (1836); 6. Pilsbry & Sharp (1897).

1939), *Emarginula solidula* e *Ancylus gussonii*, sebbene elencati anche nel "Catalogo", erano stati già descritti dallo stesso Costa (1829) in un precedente lavoro sui molluschi dell'Isola di Pantelleria.
Il "Catalogo" di Costa (1830) è scaricabile dal sito http://archive.org/details/catalogosistemat00costa.

Ringraziamenti

Si ringraziano Massimo Cretella, Rafael La Perna, Francesco Pusateri e Riccardo Giannuzzi-Savelli per i preziosi suggerimenti e la rilettura critica del lavoro.

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Fast and massive settlement of boring bivalves on coral slabs at Taboga Islands, Eastern Pacific, Panama

Karl Kleemann*

* Department of Palaeontology, University of Vienna, Geozentrum, UZA II, Althanstr. 14, A1090 Vienna, Austria
karl.kleemann@univie.ac.at

Abstract
Hundreds of natural recruits were observed on coral slabs exposed for five to six months at Urabá Island, Taboga Islands, Eastern Pacific in the course of experiments with chemically boring bivalves. Based on the size range of the specimens, the recruitment was a very fast phenomenon where many settled probably within days, many more during the following weeks. Recruits of the most common species, the mytilid *Lithophaga (Leiosolenus) aristata* (Dillwyn, 1817), reached up to 16.3 mm in length after 165 days during "winter" experiments. Densities of up to 5 borehole orifices per cm^2 were found. These results strongly contrast with results from previous recruitment experiments conducted in the tropical waters of the northern Red Sea, the Australian Great Barrier Reef and French Polynesia. Differences in recruitment on experimentally exposed substrates and possible reasons for the fast and intense settlement of boring bivalves at Urabá Island are discussed. For the latter, firstly the generally high organic turnover rate, and secondly the larval abundance of boring bivalves at the beginning of experiments appear to be largely responsible for the results.

Key Words
Bioerosion, corals, bivalves, recruitment, *Lithophaga*, E Pacific.

Riassunto
Centinaia di colonizzazioni sono state osservate su lastre ottenute da colonie di coralli esposte per un periodo compreso tra cinque e sei mesi nelle acque dell'Isola di Urabá, presso le Isole Taboga (Pacifico orientale), nel corso di esperimenti su bivalvi perforanti con modalità chimica. Sulla base delle dimensioni degli esemplari, la colonizzazione risulta essere stata molto veloce, con molte larve che si sono impiantate entro pochi giorni, e molte di più durante le settimane successive. La specie più comune, il mitilide *Lithophaga (Leiosolenus) aristata* (Dillwyn, 1817), ha raggiunto una dimensione massima di 16,3 mm di lunghezza dopo 165 giorni, durante la fase sperimentale "invernale". Per i bivalvi perforanti, è stata riscontrata una densità massima pari a 5 perforazioni per cm^2. Questi risultati contrastano fortemente con quelli ottenuti da precedenti esperimenti di colonizzazione naturale condotti nelle acque tropicali del Mar Rosso settentrionale, della Grande Barriera Australiana e della Polinesia Francese. Vengono discusse le differenze nella colonizzazione di substrati esposti sperimentalmente e i possibili motivi della veloce ed intensa colonizzazione da parte di bivalvi perforanti nelle acque dell'Isola di Urabá. I motivi sembrano soprattutto rappresentati da un tasso di *turnover* organico generalmente alto, e abbondanza di larve di bivalvi perforanti nell'area investigata.

Parole chiave
Bioerosione, coralli, bivalvi, colonizzazione, *Lithophaga*, Pacifico orientale.

Introduction

Since the early publication of the extensive and annotated bibliography on marine borers by Clapp & Kenk (1963), one main focus of interest by the scientific community has been their influence in reef habitats. In such a perspective Neumann (1966) introduced the term bioerosion in his study of boring sponges, expanding the process to include abrasion by grazers as well. A first comprehensive review on the destructive action of coral reefs by organisms (Hutchings 1986) was further implemented by the bibliographic overview of micro- and macroscopic bioerosion (Radtke et al., 1997), and, more recently by the study of Wisshak & Tapanila (2008, and references therein).

Research on micro- and macro-borers covers a wide range of recent and fossil situations. Apart from studies focussed upon certain groups or genera and species of bioeroders, increasing interest has been devoted to their life-cycle and co-occurrence, including succession rates and inter-specific competition. Field experiments were conducted with exposed substrates in various designs for micro- and/or macroborers. Microborers, such as bacteria, fungi and cyanophytes, can already be observed in carbonate substrates after a few days or weeks of exposition (Radtke et al., 1996, 1997; Vogel et al., 1996, 2000; Gektidis 1999; Tribollet et al., 2002; Tribollet & Golubic, 2005). Macro-borers, such as polychaetes, sponges and bivalves, generally colonize freshly available substrates later (Hutchings, 1981, 2008; Hutchings & Murray, 1982; Hutchings & Bamber, 1985; Kiene & Hutchings, 1985, 1994; Hutchings & Peyrot-Clausade,

1989, 2002; Hutchings et al., 1992; Peyrot-Clausade et al., 1995; Pari et al., 1998, 2002).

Within the community of borers, individual succession rates and times of reproduction and settling on available substrates greatly influence the sequence of borers and their composition in early and "mature" communities. This raises key questions such as: which species will be pioneers and what interactions will follow, which will succeed and potentially dominate colonisation and "mature" communities, which will have the greatest impact on the boring process.

In bivalves, successful settlement was recorded after two or three years and only in very low numbers in experiments conducted at the Australian Great Barrier Reef (Hutchings, 1981; Hutchings & Murray, 1982; Hutchings & Bamber, 1985; Kiene & Hutchings, 1985; Sammarco & Risk, 1990; Tribollet et al., 2002; Tribollet & Golubic, 2005), in French Polynesia (Pari et al., 2002), and in the northern Red Sea (Hassan, 1998). Nevertheless, results in bioerosion intensity can differ considerably according to geographical location, season and food supply conditions (Highsmith, 1981, 1983; Hallock, 1988; Scott et al., 1989; Sammarco & Risk, 1990; Hutchings et al, 1992; Tribolett et al., 2002). Kleemann (1990) reported on the growth and boring rates of bivalves inserted in coral slabs and mentioned only briefly the presence of natural recruits. The present article focuses on the latter and provides evidence for a very fast, numerous and successful settlement of lithophagine bivalves. Being in striking contrast to earlier results, this recruitment is discussed and probable hypotheses forwarded.

Material and methods

Zooxanthellate scleractinians, mainly *Siderastrea siderea* (Ellis & Solander, 1786), were collected from Caribbean coral reefs on two occasions by snorkelling in front of the breakwater at Fort Randolph, Colón, Panama. The Atlantic side was chosen because no suitable substrates could be obtained on the Pacific side. Carbonate substrates occurring near the Naos laboratory of the US Smithsonian Institution and at Taboga Islands proved to be already heavily infested and eroded by borers. The sampled corals were transported still wet back to the Naos laboratory the following day (by train: Nov. 1981), or the same day (by car: May 1982), for further treatment. 3.5 to 7-cm-thick slabs were cut using a hand saw from the coral heads. Once in the laboratory, young boring bivalves, by large belonging to lithophagine mussels, were placed into closely fitting, previously drilled and measured artificial holes in the slabs (Kleemann, 1990). After a few days in tanks with running seawater, the inserted bivalves usually had secreted a new byssus functional to their internal stabilization, and thus facilitating their further handling. The slabs were fastened inside mesh-wire cages which were shipped to the wreck at Urabá Island's East coast and firmly attached inside the iron hull in 1-2 m depth at low tide (Kleemann, 1990: fig. 3). In most cases, the natural upper side of the slabs was oriented up and only exceptionally upside down to save space. The cut sides, facing sideways, were relatively smooth and typically nearly upright in orientation during exposure. The sides with inserted bivalves were oriented toward the centre of the mesh-wire cages. The mesh width, 11-12 mm in diameter, was chosen to keep off larger potential predators such as fish and crabs. The cages also facilitated transport and attachment of the experimental material inside the wreck.

Experiments were performed in two seasons. In the "winter" experiments, corals were brought into the field in two parts on 5 and 9 Nov. 1981, containing 302 and 328 bivalves respectively. Cages with coral slabs were recollected on 17 and 20 April 1982 and had been exposed for 165 respectively 163 days. They were examined first superficially and cleaned by scratching off most of the fouling organisms. This yielded a better view from all sides and of the superficial boring traces. The slabs were then carefully split into pieces with hammer and "slit"-chisel for detailed investigation. In the "summer" experiments, new coral slabs, either free of or with inserted bivalves, and some old coral fragments were exposed for 174 days, from 10 May to 1 Nov. 1982.

Results

The recollected mesh-wire cages were partly covered by a dense variety of fouling organisms, as were the slabs inside. The latter had to be cleaned of the larger foulers, including bryozoans, sedentary polychaetes, cirripeds and oysters, by brushing and scraping. This procedure also revealed an intense settlement by veligers (larvae) of boring bivalves during the "winter" experiments. This was evident in the development of numerous boreholes of juvenile lithophagines, corresponding to dozens of recruits per coral slab (**Figs 1-5**). The most common bivalve species was *Lithophaga (Leiosolenus) aristata* (Dillwyn, 1817); in addition several *L. (Leiosolenus) plumula* (Hanley, 1843) and a few recruits of *L. (Leiosolenus) attenuata* (Deshayes, 1836) were also identified (Kleemann, 1986a). A wide size range was particularly evident in the dominating *L. aristata* recruits, where shell length varied from about 2-16 mm after maximally 165 days (**Figs 1, 3B**). Many recruits had grown so fast, reaching a maximal shell length of 16.3 mm, that several specimens could be used in the follow-up "summer" experiments to gain more boring and growth rates (Kleemann, 1990).

The coral tissue of the first three slabs, cut and implanted with boring bivalves, survived both the above-mentioned handling and exposure process. The coral tissue had spread a few millimetres onto the cut sides. The living tissue prevented any settlement by veligers of dead-coral boring lithophagine species there (see discussion). In later prepared slabs, coral tissue did not survive. The tissue of the individual slabs that did not

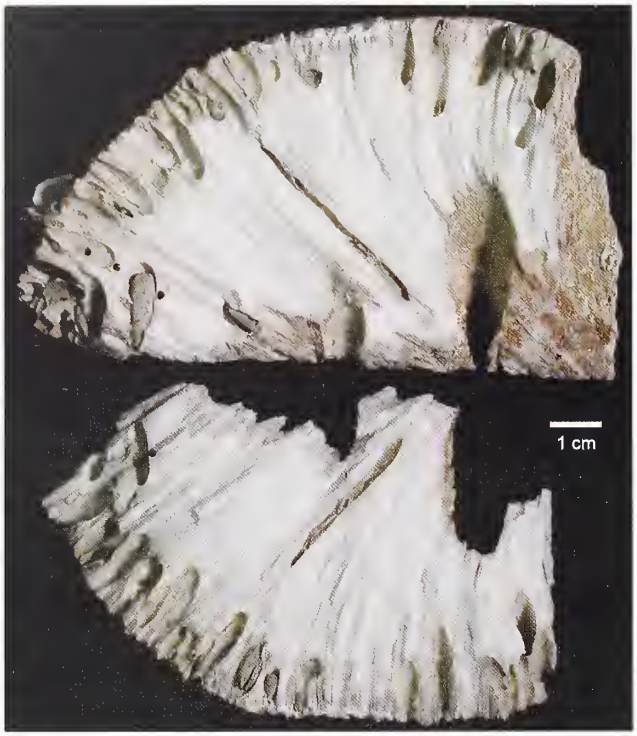

Fig. 1. *Siderastrea siderea*. Split open to exhibit the many boreholes and recruits of *L. (Leiosolenus) aristata* along the curved outline of the coral. Their wide range in length demonstrates repeated spatfall during a prolonged settling season in "winter" (beyond individual differences in post-settlement growth). Four polychaete borings are also visible: centrally one fairly straight and deeply penetrating boring, plus three cross sections, about 2 mm in diameter, on the left. Photo C. Baal.

Fig. 1. *Siderastrea siderea*. Superficie di frattura mostrante molte perforazioni e colonizzazioni da parte di *L. (Leiosolenus) aristata* visibili lungo il contorno della colonia. L'ampia variabilità in dimensioni dimostra ripetuti impianti di larve durante l'intero periodo "invernale" dell'esperimento (oltre a differenze nell'accrescimento successivo all'impianto). Sono visibili anche quattro perforazioni da policheti: al centro, una perforazione piuttosto rettilinea e molto profonda, assieme ad altre tre, a sinistra, con sezione di circa 2 mm. Foto C. Baal.

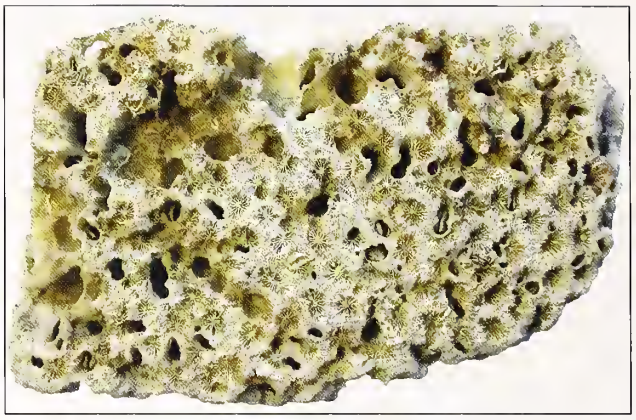

Fig. 2. *Siderastrea siderea*. Fragment in top view, 6 x 4 cm. The former "natural" surface structure is pitted by many, variously wide orifices and eroded boreholes of mainly *L. aristata*, indicating repetitive settlement of recruits, mostly during "winter". Photo K. Kleemann.

Fig. 2. *Siderastrea siderea*. Superficie superiore di un frammento di dimensioni 6 x 4 cm. La superficie "naturale" della colonia presenta molte perforazioni, di varie dimensioni, in prevalenza da parte di *L. aristata*, indicative di ripetuti impianti di larve in gran parte avvenuti durante la fase "invernale". Foto K. Kleemann.

survive probably died early on after exposure to air before being returned into seawater. The effects the decaying coral tissue on the beginning of colonisation and succession of settlers remain unknown.

Except for the first three slabs, new borings were dominantly situated on the previously live surfaces. In *S. siderea*, this surface normally consists of 3-4 mm wide, shallow calices, filled with densely packed, narrow and fine-grained septa (**Figs 2, 3A, 5A**).

Aggregations of more than five borehole orifices per cm^2 were often recorded on other natural surfaces and occasionally occurred on the cut sides of the slabs as well. On the latter, they were mainly situated near the edges towards the natural surface (**Fig. 4**). Generally, borings in the cut sides of *Siderastrea* were fewer but still common (**Figs 4, 5D**).

While numerous new orifices of bivalve boreholes were found in the slabs after the "winter" experiments, much fewer new borings and only very young or small recruits were found after "summer" (see discussion, **Fig. 5A-D**).

A single recruit of a boring crenellid bivalve, *Gregariella coarctata* (Carpenter, 1856), was also found (Kleemann, 1986b). The specimen measured 6.7-3.6-2.8 mm in length-width-height; its borehole depth was 8.7 mm and the borehole aperture 2 mm wide. For comparison: during the same time, three inserted *G. coarctata* specimens had grown 5.2 mm in length from 7.9 to 13.1 mm; 5.5 mm from 11.7 to 17.2 mm; and 1.4 mm from 18.6 to 20.0 mm respectively.

Discussion

In recent decades, several field experiments were conducted to analyse the contribution of marine borers in the erosional processes of coral reefs and to assess the balance between reef growth and decay. Exposing experimental substrates for different periods of time is one method to obtain results on colonisation, settlement, growth and boring rates as well as on the succession of various bioeroders. In such experiments, calcareous substrates of different origin and size were exposed in the field under different conditions. These conditions (locality, season, depth, etc.), depended on the respective (main) goal, e.g. assessing the amount of accretion versus erosion, general observations on the succession of micro- and/or macro-borers, or the study of specific abrading or boring organism groups.

For studying micro-borers, the experimental substrates can be small and are easily selected of various origin and texture, e.g., ooids (Gektidis, 1997), little pieces of Iceland spar crystals, mollusc shells and reef corals, often trimmed to about one or a few cm in largest dimension (Rützler & Rieger, 1973; Radtke et al., 1996; Vogel et al., 2000; Radtke & Golubic, 2005).

For macro-borer investigations, experimental substrates need to be larger, reducing the choice of suitable material. Several authors used rectangular blocks cut from live *Porites* in variable sizes, e.g., 7.5 x 5 x 1 cm (Davies & Hutchings, 1983), 5 x 5 x 8 cm and 10 x 10 x 2 cm

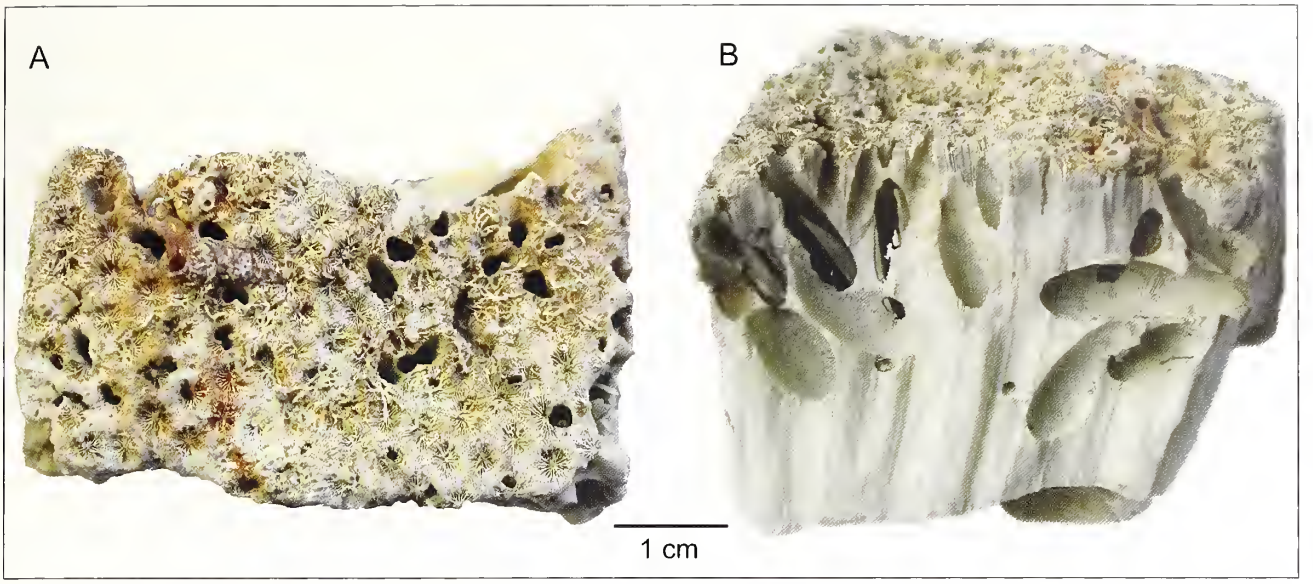

Fig. 3. *Siderastrea siderea*. **A.** Another fragment in top view, after removal of larger fouling organisms (many tiny and some bigger sedentary polychaete tubes remain). Note the density and the differing size of borehole orifices, figure-of-eight-shaped in *L. aristata* and round in *L. plumula*, two are situated in the right lower corner. Slab width (across) 53 mm. **B.** Same fragment as in Fig. 3A. The split open surface exhibits numerous borings of *L. aristata*, several intersecting in intra-specific space competition, aggregated at slab edges. A few polychaete borings in cross section are near the photo bottom. Photos K. Kleemann.

Fig. 3. *Siderastrea siderea*. **A.** Superficie superiore di un frammento dopo la rimozione degli organismi incrostanti più grandi (molti tubi di policheti sedentari di piccole dimensioni ed altri di maggiore taglia sono ancora in posto). Si noti l'elevata densità e le diverse dimensioni delle perforazioni, a forma di otto in *L. aristata* e circolari in *L. plumula*, due ubicate presso l'angolo inferiore destro. Ampiezza del campione 53 mm. **B.** Stesso frammento. La superficie di frattura mostra numerose perforazioni di *L. aristata*, alcune delle quali si intersecano in seguito a competizione intraspecifica per lo spazio. Sono presenti anche perforazioni da policheti (in sezione) nella parte inferiore. Foto K. Kleemann.

(Hutchings et al., 1992), 8 x 4 x 4 cm (Hutchings & Peyrot-Clausade, 2002), and 8 x 8 x 5 cm (Tribollet et al., 2002), 200-500 cm^3 (Kiene, 1985), or discs, 1 cm thick and 10 cm in diameter (Kiene, 1989). The experimental substrates are usually pristine in the beginning (Hutchings, 1981; Kiene, 1985; Hutchings & Peyrot-Clausade, 1989; Kiene & Hutchings, 1992; Chazottes et al., 1995; Hassan, 1998; Hutchings & Peyrot-Clausade, 2002; Hutchings & al., 2005; Osborne et al., 2005; Hutchings 2008). Substrates can be brought directly into contact with potential borers (Rützler & Rieger, 1973), or may already carry specimens of boring species (Kleemann, 1986b, 1990). In the present "winter" experiments, mainly live Caribbean *S. siderea* heads were chosen as a substrate for technical reasons. This was mainly because no suitable substrate was available for the experiments at the Pacific side (Urabá Island). There, only very few coral species were present, consisting of small patches of low growing *Pocillopora* thickets at about 2 m depth and a few massive *Pavona* and *Porites* colonies in about 5-7 m. Except the uppermost 10 cm below the live tissue in massive corals and the branch-tips of *Pocillopora*, all other carbonate substrates were already inhabited by various borers (Hutchings 1986) and strongly eroded. The live corals apparently grew only slightly faster than the rate with which they were being eroded from below. The borers probably consisted mainly of boring bivalves and sponges based on briefly lifting larger colonies from the sea floor by hand.

The eastern Pacific *Pavona* and *Porites* species serve as hosts for the associated *L. (Leiosolenus) laevigata* (Quoy & Gaimard, 1835; including *L. (Leiosolenus) lancocki* Soot-Ryen, 1955, and of later authors). Particularly *Porites* colonies were additionally riddled by *L. laevigata* bivalves from above (Kleemann 1982: fig. 9). Therefore, live corals were collected at the Caribbean side of Panama for the experiments. The chosen *S. siderea* colonies, somewhat flat-spherical or loaf-shaped, were abundant and big enough to be cut into ~5-7 cm thick slabs. Most showed no macro-borers, except on dead parts. One sample contained a single specimen of *L. (Leiosolenus) appendiculata* (Philippi, 1846) (= *Lithodomus bisulcata* Orbigny, 1853: Kleemann, 2009).

Recruitment of boring organisms takes place by larvae which settle on the substrate, metamorphose and quickly bore into it (Hutchings, 1986). Micro-borers usually play a role as pioneers of the endolithic community. Their activities facilitate and support the later settlement of macro-borers. The latter are generally handicapped by a seasonally restricted spawning period for reproduction and recruitment once a year. Distinct seasonality of recruitment has also been noted in polychaetes (Hutchings & Murray, 1992; Hutchings & Peyrot-Clausade, 2002). Several polychaete borings were found in the slabs (**Figs 1, 7**).

In the succession of borers in newly available substrates at Lizard Island, Australian Great Barrier Reef (GBR), polychaetes played an important role in the initial stages of bioerosion (Hutchings, 1981; Hutchings & Bamber, 1985). Kiene & Hutchings (1994) suggested that the age of the experimental substrates may strongly influence the nature of succession by macroborers and the suitability for further recruitment. In the present case, the coral blocks contained an artificial *Lithophaga*-communi-

ty from the start of the "winter" experiments. The presence of these adults during the settling season may have triggered the prompt "invasion" of con-specifics and promoted the abundant and successful settlement of recruits. I hypothesise that coral-associated *Lithophaga* (Kleemann, 1977, 1980, 1982, 1995, 2008; Scott 1988a, b; Kleemann & Hoeksema, 2002; Kleemann & Maestrati, 2012) benefit if they can find their proper hosts actively based on chemical traits ("smell") and also if con-specifics are already present, providing a good chance for a successful maintenance of the population.

At Lizard Island, GBR, polychaetes were important in the early stages of bioerosion of newly available coral substrate. Particularly *Polydora* species recruited within three months and *Dodecaceria* species within three to six months of exposure, probably facilitating subsequent recruitment by the sponges, sipunculans and molluscs that dominate 'mature' boring communities (Hutchings, 2008). Recruitment of boring polychaetes varies according to the type of substrate available, season and geographical location, along with environmental factors such as light, water quality, depth, and wave exposure (Hutchings, 2008). These factors may influence bivalve recruits as well. Generally, any broader interpretations of local results from bioerosion studies must be undertaken with caution.

Although polychaetes also recruited in the present experiments at Urabá Island, Taboga Islands (**Figs 1, 7**), lithophagine bivalves were the dominant settlers of the boring community and apparently preferred upper surfaces. The previously live coral surface of the exposed slabs appeared to be most attractive to the veligers (**Figs 1-3, 5**), followed by an adjacent narrow part on the cut sides (**Fig. 4**). The surface structure of the sides themselves was rather smooth and thus probably less attractive, providing fewer niches to settle. Beyond the orientation of the surfaces, the direction and velocity of the larvae-carrying water flow may also play a significant role in settlement results (Seilacher, 1969).

Spatfall at Urabá Island was high, particularly by *L. aristata*, of which a remarkable number survived for at least several weeks to months. This recruitment and survival took place despite strong space competition by mainly fouling and encrusting organisms along with a few other endozoans. The latter included related *L. plumula* and *L. attenuata* as well as unidentified polychaetes.

The natural coral surface structure appeared to be more frequently chosen and penetrated than the hand-saw cut sides. The small orifices of bivalve recruits, apart from the artificial boreholes, were detectable only after removing the fouling organisms from the slabs. Settling veligers of boring bivalves were no doubt hindered by this epifaunal space competition, e.g., oysters reaching up to 40 mm in diameter at the end of "summer" exposure (**Fig. 6**). Overgrowth and closure of already existing boreholes did occur, whereby larger boring bivalves sometimes managed to keep their borehole orifices open with their siphons. The dense aggregations of fouling and encrusting organisms and their rapid growth point

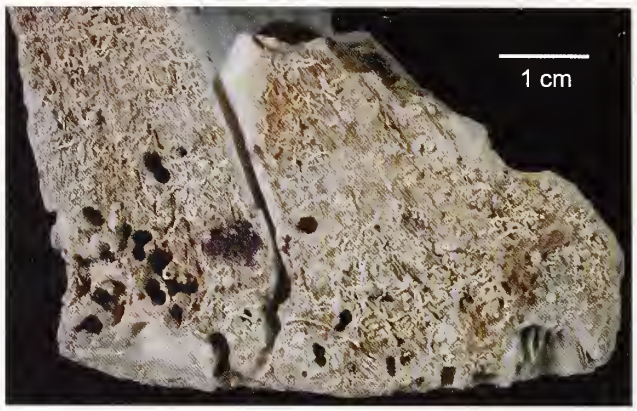

Fig. 4. *Siderastrea siderea*. New *L. aristata* borehole openings, aggregated on the cut side, near the natural coral surface (at bottom). Larger epifauna, e.g., cirripeds and tunicates, were scraped away, over one hundred tiny tubes of sedentary polychaetes remain. Photo C. Baal.

Fig. 4. *Siderastrea siderea*. Nuove perforazioni da parte di *L. aristata* concentrate presso il margine della sezione, vicino alla superficie naturale della colonia (in basso). L'epifauna di maggiori dimensioni, quali cirripedi e tunicati, è stata asportata, mentre circa un centinaio di sottili tubi di policheti sedentari sono ancora presenti. Photo C. Baal.

to a high organic turnover rate at Taboga Islands. This may reflect up-welling in the Eastern Pacific, which seemed particularly intense at Urabá Island.

In principle, local larval abundance should correspond with the local population of adults. Local *L. aristata*, the most common dead-coral boring bivalve, and probably other lithophagine species have an extended settling period, presumably starting already in October. Accordingly, "winter" experiments were colonized immediately over a period of several weeks, as indicated by the size range of recruits (**Figs 1, 3B**). "Summer" experiments displayed a sensibly lower infestation by lithophagine recruits and, considering their small size, most likely only in the last month, October 1982. A simultaneous, coincidental or brief settlement and undisturbed development of young bivalves should yield a single and narrow size group. Prolonged settlement or, less likely, repeated spatfall over a year will yield a much wider size range of recruits of the same year.

During a parallel study on the settling preferences of Eastern Pacific dead-coral boring bivalves in the "summer" experiments, I added uninhabited blocks of various coral texture (apart those with inserted specimens). This was designed to determine the influence of skeletal structure (Kleemann, 1990). Unfortunately, too few recruits were found after the "summer" period for a more detailed analysis but this attempt did provide further proof of bivalve settlement at least within weeks to a few months on newly available substrates. The seasonal influence on *L. aristata* recruitment was striking. Considering the wide size rage of its recruits after the "winter" period, a very prolonged settling season can be assumed at least for this species. I consider that the size differences in the recruits mainly reflect the varying available amount of time after metamorphosis and less the micro-environmental parameters (food and space competition). Several *L. aristata* recruits had grown so fast that they could be used in the follow-up "summer"

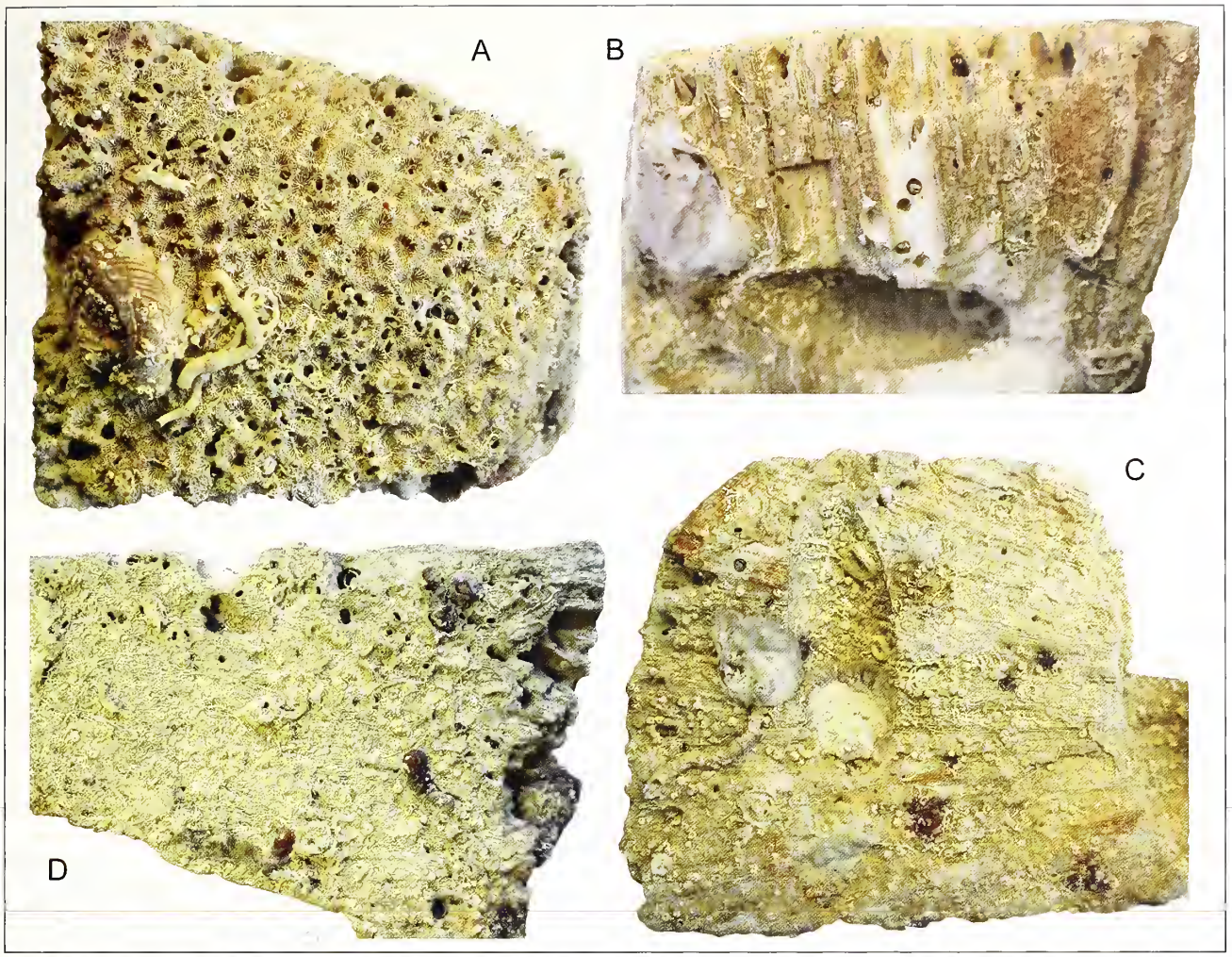

Fig. 5. *Siderastrea siderea*. **A**. Top view, slab thickness 6 cm. Many borehole orifices are irregularly dispersed over the surface. Some very small ones may stem from Oct. 1982 recruits, others were smothered by encrusters such as cirripeds, now removed. **B**. Above the longitudinally opened, big old borehole, note several minute orifices, dark dots, and a few small boreholes in cross-section, partly with remaining shells, of new recruits. They probably settled in Oct. 1982, close to the end of "summer" experiments. **C**. After "winter", the split surface had showed only two longitudinally opened, big boreholes, one in the middle and part of another at right, of inserted specimens. Now, the 7 x 6 cm area is densely covered by various polychaete tubes and a few orifices of bivalve borings, namely at the left. Recruits of oysters indicate this surface was the underside during the "summer" experiment. **D**. This side, cut not split, was in contact with the mesh-wire during "winter". Some of the smallest borehole orifices may belong to October 1982 recruits (see text). Note the strong bioerosion and bioaccretions by encrusters on the right edge. Photos K. Kleemann.

Fig. 5. *Siderastrea siderea*. **A**. Superficie superiore di una sezione spessa 6 cm. Sono presenti molte perforazioni irregolarmente distribuite. Alcune perforazioni molto piccole potrebbero risalire alla colonizzazione dell'Ottobre 1982, mentre altre sono state ricoperte da incrostanti, quali cirripedi, ora rimossi. **B**. Al di sopra della grossa perforazione sezionata longitudinalmente, si notano diverse piccole aperture, come puntini scuri, ed alcune piccole perforazioni sezionate, in parte ancora con conchiglie all'interno. Molto probabilmente esse risalgono all'Ottobre 1982, verso la fine dell'esperimento "estivo". **C**. Dopo l'esperimento "invernale" la superficie di frattura mostrava solo due ampie perforazioni, una al centro e parte dell'altra a destra dell'esemplare inserito sperimentalmente. Adesso, l'area di 7 x 6 cm è densamente ricoperta da tubi di policheti e sono presenti alcune perforazioni da bivalvi a sinistra. La colonizzazione da parte di ostriche indica che questa superficie era posizionata inferiormente durante l'esperimento "estivo". **D**. Questo lato, non spezzato ma sezionato, era in contatto con la rete durante l'esperimento "invernale". Alcune delle perforazioni più piccole potrebbero appartenere alla fase di Ottobre 1982 (si veda nel testo). Si noti l'intensa bioerosione ed il concrezionamento biologico sul margine destro. Foto K. Kleemann.

experiments on boring and growth rates. Shell length reached up to 21 mm after both periods. Considering the observed growth rate and a maximal shell length of about 38 mm, a local population succession rate of one to two years seems plausible (Kleemann, 1990).

The present findings of fast and intense bivalve settlement in newly exposed substrates are in contrast to several publications in which boring bivalves were reported either missing or to occur in small numbers only after one or more years. For example, they were missing after one year at the GBR (Tribolett et al., 2002), after two years at Moorea, French Polynesia (Chazottes et al., 1995). They occurred after two years at Aqaba, Red Sea (Hassan, 1998), after three years at the GBR (Kiene & Hutchings, 1994), as well as after two years at inshore, after four years at outer reef sites at the GBR (Osorno et al., 2005). As documented by these and comparative studies from three more sites at the GBR (Sammarco & Risk, 1990), boring bivalves seem to be a minor actor in bioerosion. Kiene (1985) found bivalves, *Gastrochaena* and *Lithophaga*, usually represented by only one or two borings in substrates after two to three years of exposure; none were identified after one year at Lizard Island, GBR.

Investigating the internal bioerosion of *Porites* across the Australian GBR, Sammarco & Risk (1990) noted a

significant decrease with distance offshore; the abundance of bivalves and sponges decreased most significantly, and boring bivalves dominated inshore reefs. The latter can be explained by the fact that *Porites* is a well-known host of *L. (Leiosolenus) laevigata* (Kleemann, 1980, 1982, 1995). Although those authors did not mention the species or its association, the latter can be recognised by the numerous traces illustrated in an x-ray (Sammarco & Risk, 1990: fig. 5B), indicating successive bivalve generations in a sliced coral skeleton from Orpheus Island, only 14 km from shore. There, better nutrition than further offshore can be expected, as discussed above.

Musso (1993) investigated the skeletal degradation after death in three *Acropora* species at Lizard Island, GBR, Australia. Two of them, *cuneata* (Dana, 1846) and *brueggemanni* (Brook, 1893) are members of *Isopora*, a previous subgenus of *Acropora*, now in genus rank (Wallace et al., 2007). Being the host of *L. (Leiosolenus) kuehnelti* Kleemann, 1977, *Isopora* species may contain such bivalves (Kleemann, 1977, 1980, 1995). Unsurprisingly, Musso (1993) found bivalves in *I. cuneata* and *I. brueggemanni*, more in the former, a massive species, and less in the latter, being thin-branched (Kleemann, 1995: pl. 1, fig. 1). Those bivalves, however, were already present and killed together with the hosts at the beginning of Musso's experiments and did not develop during the experiments as suggested.

The factors that could influence the present results may include the size of the experimental substrates, the occurrence of inserted bivalves, the still living or decaying coral tissue on part of the slabs, and the protection by mesh-wire from larger predators such as fish and crabs. The shaded locality in the wreck probably reduced pressure from algal overgrowth, but not from various other space competitors, particularly from encrusting cirripeds and fast spreading oysters (**Fig. 6**). In principle, lithophagine specimens can keep their borehole openings free from lateral overgrowth using chelating secretions from the siphons as they widen the openings during bivalve growth. This is very well demonstrated in coral associates. To some extent, dead coral borers may be successful in preventing lateral overgrowth, if it is not too fast and compact. Veligers probably settle preferably on substrates already inhabited by con-specifics, which may be sensed chemically.

Substrate orientation – flat or steep, bright or shaded as on upper or lower sides of surfaces – and structural differences may influence colonisation patterns of boring bivalves. Note that the colonisation plasticity of *L. aristata* was recently investigated in south eastern Brazilian rocky shores. Lange et al. (2012) found this introduced species in highest densities of 100.0 ± 15.3 m^{-2} in 0.5 m at Guaíba Island, and 143.3 ± 26.1 m^{-2} in 3 m at Guaíba Terminal, Sepetiba Bay, in December 2005.

Astonishingly, the living surface of the first three prepared slabs survived the "winter" period and prevented veliger settlement. If the slabs would have been from Caribbean *Porites astroides* Lamarck, 1816, instead of *S. siderea*, veligers of *L. laevigata* would probably have set-

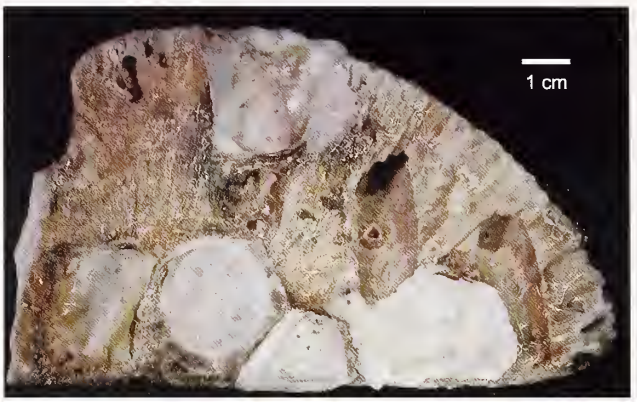

Fig. 6. *Siderastrea siderea*. Underside of a re-exposed fragment, covered about half by oysters, up to 40 mm in diameter, further by polychaete tubes and cirripeds (some left over in the old, longitudinally split open boreholes). No new *Lithophaga* boreholes visible. Photo C. Baal.

Fig. 6. *Siderastrea siderea*. Superficie inferiore di un frammento riesposto, ricoperto per circa metà da ostriche, di dimensioni fino a 40 mm, oltre che da tubi di policheti e cirripedi (alcune all'interno di vecchie perforazioni sezionate longitudinalmente). Non è visibile alcun foro di recente formazione da parte di *Lithophaga*. Foto C. Baal.

tled as they do on their eastern Pacific hosts, *P. lobata* Dana, 1846, and *P. panamensis* Verrill, 1866. Glynn et al. (1972: p. 505) mentioned *L. (Leiosolenus) hancocki* Soot-Ryen, 1955 (a junior synonym of *laevigata*; Kleemann, 1980), from gut contents of triggerfish, *Balistes*. The Eastern Pacific appears to be unique in that many bivalves occur in the live part of corals (Highsmith, 1980). Highsmith et al. (1983) noted that lithophagine bivalves inhabiting *P. lobata* are three times more abundant in the upwelling enriched Gulf of Panama than in the adjacent but less productive Gulf of Chiriqui (mean 4220 versus 1350 m^{-2}) and that the bivalves grow approximately twice as fast in the former location. Scott et al. (1989) reported *P. lobata* inhabited by *L. laevigata* and *aristata* (but the latter infests only dead parts of live coral), with mean densities of 3060, 1870, and 480 m^{-2} of coral surface in Panama, Costa Rica and Galapagos, respectively. High densities were also noted in *Porites* colonies at Lizard Island, GBR (Kleemann, unpubl.). In the northern Red Sea, even denser populations were observed of three different *L. (Leiosolenus)* species associated with their host species of (1) *Montipora*, (2) *Cyphastrea* and *Echinopora*, and (3) *Stylocoeniella*, respectively (Kleemann, 2008). I corroborate the view of Highsmith (1981) that bioerosional damage to corals depends primarily on the amount of skeletal surface not covered by live tissue. I also support the view that species differences in mean skeletal excavation reflect differences in their ability to protect the skeleton from boring organisms by maintaining live tissue over it. Highsmith et al. (1983) mentioned that Glynn et al. (unpublished) had found boring bivalves more abundant in corals affected by upwelling than at less affected sites at Galapagos Islands. Highsmith (1980) had already found that bioerosion is positively correlated with plankton primary productivity because two major borers, bivalves and sponges, are planktivores. For the role of nutrient availability in bioerosion see also Hallock (1988, and references there-

Fig. 7. *Siderastrea siderea*. Traces of polychaete borings, 1.5 mm in cross-section, in coral fragment and a right valve of *L. aristata*. Note the septal structure of *S. siderea* corallites crossed by an old *aristata* boring. Photo K. Kleemann.

Fig. 7. *Siderastrea siderea*. Perforazioni da policheti con diametro di 1,5 mm in un frammento di colonia comprendente anche una valva destra di *L. aristata*. Si noti la struttura settata dei coralliti di *S. siderea*, messa a nudo da una vecchia perforazione di *L. aristata*. Foto K. Kleemann.

in). Comparing bivalve boring and growth rates of lithophagine bivalves in the Caribbean and Eastern Pacific corroborates these findings (Kleemann, 1990).

Conclusions

At Urabá Island, Taboga Islands, Panama, Eastern Pacific, large numbers of lithophagine veligers settled on coral slabs, metamorphosed to bivalves and bored into the substrates within days or at most in a few weeks. Surviving recruits of *L. aristata*, occurring in highest numbers, grew up to 16 mm in length during maximal 165 days in "winter" experiments. During "summer", recruitment was relatively low and had probably only started in October, before the end of experiments 1 Nov. 1982. The present results are in strong contrast to results from investigations of the succession of macro-borers in experimentally exposed coral substrates conducted at the GBR of Australia, French Polynesia and the northern Red Sea. In all these regions, boring bivalves were either missing or were observed only after years in the succession of settling organisms.

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La malacofauna pliocenica di "Le Conchiglie", Lagune di Sasso Marconi (Bologna)

Mariella Bellagamba* (*✉), Mariabenedetta Caldarella# & Maurizio Forli°

* Dipartimento di Scienza della Terra, della Vita e dell'Ambiente (DiSTeVA) - Università degli Studi "Carlo Bo", Campus Scientifico "E. Mattei" - Loc. Crocicchia. 61029 Urbino (PU), Italia, mariella.bellagamba@uniurb.it, (*✉) Corresponding Author

via La Marmora, 37 - 96012 Avola (SR), Italia, benedettageo@gmail.com

° via Grocco, 16 – 59100 Prato (PO), Italia, info@dodoline.eu

Riassunto

È stata esaminata la malacofauna contenuta in un campione volumetrico prelevato da un affioramento all'interno dell'azienda agrituristica "Le Conchiglie", in località Lagune di Sasso Marconi (Bologna). Il campione proviene dal Membro delle Ganzole, Formazione di Monte Adone, attribuita al Piacenziano. L'associazione a molluschi, indicativa del Piacenziano inferiore-medio, è composta essenzialmente da gasteropodi e bivalvi, per un totale di 103 specie. Dal punto di vista paleoambientale, essa è indicativa di mare caldo, di tipo subtropicale, e di fondali sabbioso-fangosi con presenza di frazione grossolana, al limite tra i piani infralitorale e circalitorale. Dal punto di vista biocenotico, l'associazione corrisponde ad un ecotono fra le paleobiocenosi SFBC e DC-DE.

Parole chiave

Molluschi marini, Paleoecologia, Pliocene, Golfo bolognese.

Abstract

[*The Pliocene molluscan fauna of "Le Conchiglie", Lagune di Sasso Marconi (Bologna)*]. The molluscan assemblage from a bulk sample from the Member of Ganzole, belonging to the Monte Adone Formation, was studied for biostratigraphic and paleoecological purposes. The Ganzole Member, referred in the literature to the Piacenzian, consists of intercalating sandy and pelitic beds, cropping out in the Sasso Marconi area (Bologna, central Italy). The bulk sample, with a volume of 50 dm^3, was subdivided into 48 subsamples, one of which (C1, volume ca. 1000 cm^3) was used for studying the molluscan fauna. The assemblage consists of 103 species of gastropods, bivalves and scaphopods, for a total of 1493 specimens. Its composition is indicative of warm waters, sandy-muddy substrates with debris, between the infralittoral and the circalittoral zones. Biocenotically, the assemblage is indicative of an ecotone between the SFBC and DC-DE paleobiocoenoses. The occurrence of species which became extinct in the Late Pliocene, such as *Bathytoma cataphracta* (Brocchi, 1814), *Bela nitida* Pavia, 1975, *Eulimella subalpina* (Sacco, 1892) and *Turbonilla pliopupoides* (Sacco, 1892), together with the occurrence of *Venus foliaceolamellosa* (Dillwyn, 1817) and *Pelecyora gigas* (Lamarck, 1818), whose disappearance seems to be related to the Pliocene cooling, point to an Early-Middle Piacenzian age.

Key words

Marine molluscs, Palaeoecology, Pliocene, Gulf of Bologna.

Introduzione

"Le Conchiglie" è un centro agrituristico ubicato nei pressi di Lagune di Sasso Marconi (BO). Il suo nome deriva dall'enorme abbondanza di molluschi fossili presenti nei depositi pliocenici affioranti nell'area. Dopo una serie di campionamenti manuali sugli affioramenti, in collaborazione con il Centro Studi "Le Conchiglie", è stato prelevato un campione volumetrico allo scopo di conoscere in dettaglio la malacofauna presente, di effettuarne l'analisi paleoecologica e di definire meglio l'età.

Inquadramento stratigrafico

Durante il Pliocene, l'area da cui proviene la malacofauna studiata si trovava all'interno del golfo intrappenninico bolognese, impostatosi, a partire dall'Eocene medio, su rocce deformate e dislocate dall'orogenesi appenninica. Lungo le coste del golfo sfociavano torrenti che diedero origine a spessi strati ciottolosi, intercalati a sabbie. Essi passano gradualmente, verso l'alto, ad argille grigie, cui si intercalano strati sabbiosi e lenti di ciottoli. Queste rocce sono riunite nella Formazione di Monterumici, attribuibile al Pliocene inferiore (subzona a *Globorotalia puncticulata* di Colalongo & Sartoni, 1979 in Ricci Lucchi & al., 1981). Ad essa si sovrappongono le arenarie della Formazione di Monte Adone, suddivisa in due membri: a) Membro di Monte delle Formiche, caratterizzato da arenarie a laminazione piano-parallela o incrociata indicative di ambienti di mare basso influenzati dal moto ondoso; b) Membro delle Ganzole, costituito da arenarie fini, intercalate a peliti sabbiose, di ambienti più distali e profondi.

Il campione volumetrico proviene da quest'ultima unità litostratigrafica, indicata con la sigla ADO 2 nel foglio 237 della Carta Geologica d'Italia. L'età della Formazione di Monte Adone, in base soprattutto ad associazioni ad ostracodi, è attribuibile al Piacenziano o, dubitativa-

mente, alla base del Pleistocene (Ricci Lucchi et al., 1981; Colalongo et al., 1982).
La località fossilifera è conosciuta dalla fine del XIX secolo (Foresti, 1868) ma non risulta più segnalata se non recentemente da Cirone et al. (1997) e da Ceregato et al. (2010), in occasione di studi sui molluschi della collezione Foresti.

Materiale e metodi

Lo studio ha avuto inizio con la raccolta manuale di numerosi esemplari sulla superficie dell'affioramento. Successivamente, è stato prelevato un campione volumetrico di circa 50 dm^3 dai livelli pelitico-sabbiosi, il quale è stato suddiviso in 48 sotto-campioni, secondo una matrice 8 x 6. Dei sotto-campioni, ne è stato analizzato quantitativamente solo uno (C1), con un volume pari a circa 1000 cm^3. Per facilitare l'analisi, esso è stato diviso in tre frazioni granulometriche: > 5 mm, 5-2 mm, 2-0,5 mm.
In totale, sono stati identificati 103 specie di molluschi, per un totale di 1493 esemplari. Le specie sono rappresentate da gasteropodi (53 specie), bivalvi (48 specie) e scafopodi (2 specie). In **Tab. 1** vengono elencate le specie, con la loro abbondanza (n), dominanza (%), caratteristiche autoecologiche (piano, substrato, biocenosi, habitus e trofismo), significato paleoclimatico e distribuzione stratigrafica.
Per quanto riguarda la distribuzione ecologica, le specie a prevalente distribuzione in un piano sono state conteggiate come indicative di quel piano. Le stesse informazioni, deducibili dalla tabella, sono illustrate nei grafici circolari (**Fig. 1**) dove, accanto ad ogni settore, sono riportati il numero degli esemplari e la relativa percentuale. Per semplificare l'esposizione, non sono indicati i conteggi delle singole frazioni ma il totale risultante dalle tre frazioni. Anche le specie raccolte solo manualmente, non conteggiate, sono riportate, con le loro caratteristiche autoecologiche, significato paleoclimatico e distribuzione stratigrafica, in **Tab. 1**.
Recentemente, *l'International Commission on Stratigraphy* ha posto il limite Plio-Quaternario a 2,59 M.a. per cui il Gelasiano, considerato precedentemente Pliocene superiore, è attualmente Pleistocene inferiore; si è tenuto conto di questo dato per cui si è indicato come Pliocene superiore tutto ciò che i vari autori, precedenti il 2011, segnalavano come Pliocene medio. Analogamente, si è indicato come Pleistocene inferiore le segnalazioni precedenti relative al Pliocene superiore.

Gastropoda	n	%	P	S	B	H	T	DS
Gibbula sp.	1	0,1				e-v	O	
Clelandella miliaris (Brocchi, 1814)	1	0,1	Iprof-B	FDc		e-v	E	M-Ol
Trochidae	1	0,1				e-v		
+ *Cerithium crenatum* (Brocchi, 1814)	RM		I	SFD		e-v	DT	M-Pleis
Bittium reticulatum (da Costa, 1778)	57	3,8	Sop-C	FSRD		e-v	DT	M-Ol
+ *Turritella tricarinata* (Brocchi, 1814)	13	0,9	I-C	FSD		i-v	DT	M-Pleis
Pusillina inconspicua (Alder, 1844)	1	0,1	I-C	FSD		e-v	DT	Pl-Ol
Aporrhais pespelecani (Linnaeus, 1758)	RM		I-B	FD	PrDc PrVTC	e-v	DT	M-Ol
+ *A. uttingeriana* (Risso, 1826)	RM		I-C	FSD	PrDc	s-v	DT	M-Pleis
Aporrhais sp.	3	0,2				e-v	DT	
Calyptraea chinensis (Linnaeus, 1758)	1	0,1	I-C	RSF		e-v	SP	M-Ol
Petaloconchus glomeratus (Linnaeus, 1758)	RM		I-C	RSF		e-ss	O	M-Ol
+ *Cochlis raropunctata raropunctata* (Sasso, 1827)	1	0,1	I-C	FS		i-v	CR	M-Pleis
+ *Tectonatica tectula* Sacco, 1891	5	0,3	I-B	FSD		i-v	CR	M-Pleis
Euspira macilenta (Philippi, 1844)	9	0,6	I-Csup	FS		i-v	CR	Pl-Ol
+ *Neverita olla* (de Serres, 1829)	2	0,1	I-C	SF	ExclSFBC	i-v	CR	Olig-Pleis inf
+ *Sinum striatum* (de Serres, 1829)	1	0,1	I-C	FS		i-v	CR	M-Pleis inf
Naticidae	1	0,1				i-v	CR	
+ *Ficus subintermedia* (d'Orbigny, 1852)	RM		I-C	SFc		i-v	CR	M-Pleis inf
Semicassis saburon (Bruguière, 1792)	RM		I-B	FSc	PrVB	i-v	CR	M-Ol
Epitonium commune (Lamarck, 1822)	3	0,2	m-C	FS		e-v	P	M-Ol
?(+) *Eulima boucheti* Landau, La Perna & Marquet, 2006	3	0,2	I-C	FS	PrVTC	e-v	P	Pl-Pleis inf
+ *Niso eburnea* (Risso, 1826)	RM		I-C	SFD		e-v	P	M-Pleis
+ *Bolinus brandaris torularius* (Lamarck, 1822)	1	0,1	I-C	FSD		e-v	CR	M-Pleis
Hexaplex trunculus (Linnaeus, 1758)	RM		I	SFD		e-v	CR	M-Ol
+ *Heteropurpura polymorpha* (Brocchi, 1814)	RM		I-C	FSD		e-v	CR	M-Pleis
Fusinus rostratus (Olivi, 1792)	1	0,1	I-B	FSD	PrVB	i-v	CR	M-Ol
+ *Nassarius crebricostulatus* (Bellardi, 1882)	3	0,2	I-C	FS		i-sd	N	Pl-Pleis inf
N. elatus (Gould, 1845)	1	0,1	I-C	FSD		i-sd	N	Pl-Ol
+ *N. semistriatus* (Brocchi, 1814)	29	1,9	I-C-B	FSD		i-sd	N	M-Pleis
+ *N. clathratus* (Born, 1788)	24	1,6	I-epiB	FS		i-sd	N	M-Pleis
Nassarius sp. 1	2	0,1				i-sd	N	
Nassarius sp. 2	6	0,4				i-sd	N	

Nassarius sp. 3	1	0,1				i-sd	N	
+ *Sveltia varicosa* (Brocchi, 1814)	RM		I-C	FS		e-v	O	M-Pleis
+ *Solatia hirta* (Brocchi, 1814)	RM		I-C	FS		e-v	O	M-Pleis
+ *Conus antidiluvianus* Bruguière, 1792	RM		I-C	FSD	PrVTC	i-v	CR	M-Pl
Conus sp.juv.	1	0,1				i-v	CR	
+ *Bathytoma cataphracta* (Brocchi, 1814)	RM		I-epiB	FSD		e-v	CR	Olig-Pl sup
+ *Gemmula contigua* (Brocchi, 1814)	RM		I- C-B	FSD		e-v	CR	M-Pleis
+ *Crassopleura sigmoidea* (Bronn, 1831)	2	0,1	C-epiB	SFD		i-v	CR	M-Pleis
Bela nebula (Montagu, 1803)	5	0,3	I-C	SFD	PrSFBC	i-v	CR	Pl-Ol
+ *B. nitida* Pavia, 1975	4	0,3	C-B	FS	PrVTC	i-v	CR	M-Pl sup
B. turgida (Forbes in Reeve, 1844)	1	0,1	I-C	SFD		e-v	CR	M-Ol
+ *B. vulpecula* (Brocchi, 1814)	1	0,1	C	FS		i-v	CR	M-Pleis
Mangelia cfr. *payraudeaui* (Deshayes, 1835)	1	0,1	I-C	S		e-v	CR	Pl-Ol
+ *Strioterebrum pliocenicum* (Fontannes, 1881)	RM		I-C	FSD		i-v	CR	M-Pleis inf
+ *Subula fuscata* (Brocchi, 1814)	RM		I-C	FS	PrSFBC	i-v	CR	M-Pl
+ *Terebra acuminata* Borson, 1820	RM		I-C	SFD		i-v	CR	M-Pl
+ *Basisulcata simplex* (Bronn, 1831)	RM		I-C	SFD		e-sd	CR	M-Pleis inf
+ *Pseudomalaxis aldrovandii* (Foresti, 1868)	1	0,1	I-B	FSD		e-sd	CR	Pl-Pleis inf
Chrysallida stefanisi (Jeffreys, 1869)	1	0,1	C-B	D		e-sd	P	M-Ol
+ *Chrysallida* sp.	1	0,1	C-B	F		e-sd	P	?Pl inf-sup?
+ *Eulimella subalpina* (Sacco, 1892)	5	0,3	C-B	SF		e-sd	P	Pl inf-sup
Odostomia acuta Jeffreys, 1848	5	0,3	I-C	FS		e-sd	P	M-Ol
O.conoidea (Brocchi, 1814)	3	0,2	I-B	FS		e-sd	P	M-Ol
+ *Turbonilla pliocostellatoides* Sacco, 1892	3	0,2	I	FS		e-sd	P	Pl -Pleis inf
+ *T. pliopupoides* (Sacco, 1892)	2	0,1	C	F		e-sd	P	Pl inf-sup
T. cfr. postacuticostata Sacco, 1892	5	0,3	I-C	FD		e-sd	P	Pl-Ol
Turbonilla sp.	1	0,1				e-sd	P	
+ *Acteon semistriatus* (Férussac, 1822)	4	0,3	I-C	SF	PrSFBC	i-v	CR	?M-Pleis inf
Retusa truncatula (Bruguière, 1792)	4	0,3	I-C	FSD		i-v	CR	M-Ol
+ *Cylichnina pliosimplex* Sacco, 1897	3	0,2		SF		i-v	CR	Pl
Volvulella acuminata (Bruguière, 1792)	2	0,1	I-C	SFD		i-v	CR	Pl-Ol
Ringicula auriculata (Ménard de La Groye, 1811)	20	1,3	I-B	SFD		i-v	P	M-Ol
Pluiline scabra (Müller, 1784)	1	0,1	I-B	FSD		i-v	CR	M-Ol
Roxania utriculus (Brocchi, 1814)	2	0,1	I-epiB	SFD		i-v	CR	M-Ol
Cylichna cylindracea (Pennant, 1777)	2	0,1	I-epiB	FS		i-v	CR	M-Ol
Acteocina knockeri (Smith, 1871)	3	0,2	I	S		i-v	CR	M-Ol
Scaphander lignarius (Linnaeus, 1758)	4	0,3	I-B	FSD		i-v	CR	M-Ol
Styliola subula (Quoy & Gaimard, 1827)	1	0,1				p		M-Ol
Bivalvia								
Nucula nitidosa Winckworth, 1930	45	3	I-C	FSD		s-v	DT	M-Ol
Saccella commutata (Philippi, 1844)	273	18	I-C-B	SFD	PrDE PrDC	s-v/ sd	DT	M-Ol
Lembulus pella (Linnaeus, 1758)	132	8,8	I-B	FSD		s-sd	DT	M-Ol
+ *Yoldia nitida* (Brocchi, 1814)	5	0,3	I-C	F	PrVTC	s-sd	DT	M-Pleis
+ *Ambrogia mytiloides* (Brocchi, 1814)	3	0,2	I-C	F		sb	f	M-Pleis
Anadara diluvii (Lamarck, 1805)	17	1,1	I-C	FD	PrDC PrVTC	sb	f	Olig-Ol
Glycymeris insubrica (Brocchi, 1814)	6	0,4	I-C	SFD	ExclSFBC	s-sd	f	M-Ol
Musculus cfr. *discors* (Linné, 1767)	14	0,9	m-C	FSD		e-ss	f	Pl -Ol
Atrina pectinata (Linné, 1767)	RM		I-B	FS		sb	f	M-Ol
+ *Pteria phalenacea* (Lamarck, 1819)	2	0,1	I-B	FS	ExclVTC	eb	f	M-Pleis inf
+*Pecten flabelliformis* var. *persulcata* (Sacco, 1897)	RM		I-C	FSD	ExclSGCF	e-v	f	M-Pleis inf
Chlamys varia (Linnaeus, 1758)	8	0,5	I-C	DRFS	PrDC	e-v	f	M-Ol
+ *Amusium cristatum* (Bronn, 1827)	25	1,7	I-C-B	FSD		e-v	f	M-Pleis
Anomia ephippium Linnaeus, 1758	8	0,5	I-B	RD	PrDC	e-ss	f	M-Ol
Limatula subauriculata (Montagu, 1808)	2	0,1	I-B	FSD	PrVB	eb	f	M-Ol
Limidae	1	0,1				eb	f	
Ostrea edulis (Linnaeus, 1758)	RM		m-C	R		e-ss	f	M-Ol
Neopycnodonte cochlear (Poli, 1795)	RM		I-B	FSD		e-ss	f	M-Ol
+ *Lucina orbicularis* Deshayes, 1836	2	0,1	I	F		i-sd	f	M- Pleis inf
Lucinella divaricata (Linnaeus, 1758)	8	0,5	I-C	SD	PrSFBC	i-sd	f	M-Ol
Mysella sp.	2	0,1				i-sd	f	

Cardium indicum Lamarck, 1818	RM		I-C	SFD		i-sd	f	M-Ol
Acanthocardia echinata (Linnaeus, 1758)	105	7	I-C	DS	PrDE	s-sd	f	M-Ol
+*Parvicardium vroomi pliopapillosa* (Sacco, 1899)	1	0,1	I-C	R		s-sd	f	Pl sup
P.scabrum (Philippi, 1844)	7	0,5	I-B	DFS		s-sd	f	M-Ol
+*Laevicardium subturgidum millasiense* (Fontannes, 1881)	4	0,3	C	FS		s-sd	f	M-Pleis
Spisula subtruncata (da Costa, 1778)	129	8,6	I-C	SF	PrSFBC	i-sd	f	M-Ol
Lutraria augustior Philippi, 1844	10	0,7	m-C	FD		i-sd	f	Pl-Ol
Donacilla cornea (Poli, 1791)	6	0,4	I	FS		i-sd	f	M-Ol
Solen marginatus Pulteney, 1799	13	0,9	m-I	SF	ExclSFBC	i-sd	f	M-Ol
Tellina compressa Brocchi, 1814	60	4	I-C	DFS	ExclDC	i-sd	DP	M-Ol
T. pulchella Lamarck, 1818	42	2,8	m-I	SF	ExclSFBC	i-sd	DP	M-Ol
Donax cfr. *trunculus* Linnaeus, 1758	1	0,1	m-I	S	ExclSFS	i-sd	DP	Pl-Ol
Psammobia fervensis (Gmelin, 1791)	6	0,4	I-C	DSF	ExclDC	i-sd	DP	M-Ol
+ *P.*cfr. *uniradiata* (Brocchi, 1814)	1	0,1	I-C	SFD		i-sd	DP	M-Pleis inf
P. cfr. *depressa* (Pennant, 1777)	8	0,5	I-C	SFD		i-sd	DP	M-Ol
Psammobia sp.	11	0,7				i-sd	DP	
Scrobicularia cfr. *plana* (da Costa, 1778)	8	0,5	I	FS		i-sd	DP	Pl-Ol
Abra prismatica (Montagu, 1808)	9	0,6	I-B	SD		i-sd	DP	M-Ol
A. alba (Wood, 1802)	2	0,1	I-C	FSD		i-sd	DP	M-Ol
Azorinus chamasolen (da Costa, 1778)	2	0,1	I-B	DSF	PrDC PrDE	i-sd	DP	M-Ol
(+)*Venus foliaceolamellosa* (Dillwyn, 1817)	45	3	I	S	PrSFBC	i-sd	f	M-Pl sup
V. nux Gmelin, 1791	53	3,6	I-B	FSD	PrVTC	i-sd	f	M-Ol
Chamelea striatula (da Costa, 1778)	8	0,5	I-B	FS		i-sd	f	Pl-Ol
Timoclea ovata (Pennant, 1777)	49	3,3	I-C-B	DSF	PrDC PrDE	i-sd	f	M-Ol
Dosinia lupinus (Linnaeus, 1758)	11	0,7	I-C	SFD	PrSFBC	i-sd	f	M-Ol
Dosinia sp.	2	0,1				i-sd	f	
+*Pelecyora islandicoides* (Lamarck, 1818)	15	1	I-C	SF		i-sd	f	M-Pleis inf
+ *P. gigas* (Lamarck, 1818)	RM		I	SF	PrSFBC	i-sd	f	M-Pl sup
Paphia aurea (Gmelin, 1791)	2	0,1	I-C	FSD	PrSVMC	i-sd	f	Pl-Ol
Corbula gibba (Olivi, 1792)	53	3,6	I-B	FSD		i-ss	f	Paleoc-Ol
Hiatella arctica (Linné, 1767)	1	0,1	m-B	RD		eb	f	M-Ol
Panopea glycimeris (Von Born, 1778)	RM		I-C	SF		i-ss	f	M-Ol
Xylophaga dorsalis (Turton, 1819)	1	0,1				perf		M-Ol
Cuspidaria cuspidata (Olivi, 1792)	1	0,1	I-B	FSD		i-sd	CR	M-Ol
Scaphopoda								
+ Paradentalium sexangulum (Gmelin, 1791)	2	0,1	I-C	S	PrSFBC	i-sd	DP	M-Pleis
Fustiaria rubescens (Deshayes, 1825)	13	0,9	I-B	FSD		i-sd	DP	M-Ol

Tab. 1. + = specie estinta; (+) = specie scomparsa solo dal Mediterraneo; ?(+) = specie scomparsa dal Mediterraneo ma ancora dubitativamente vivente.; = ___ taxon indicativo di acque da temperate a tropicali; = ___ taxon euritermo. RM = specie raccolta manualmente. Piano (**P**): Sop = sopralitorale, m = mesolitorale, I = infralitorale, **I** = prevalente distribuzione nell'infralitorale; C = circalitorale; **C** = prevalente distribuzione nel circalitorale; B = batiale. Substrato (**S**): S = sabbioso; F = fangoso; D = detritico; R = roccioso; c = coralligeno. Biocenosi (**B**): SFBC = Sabbie Fini Ben Classate; SFS = Sabbie Fini Superficiali; SVMC = Sabbie Fangose di Moda Calma; SGCF = Sabbie e Ghiaie sotto l'influenza di Correnti di Fondo; DC = Detritico Costiero; DE = Detritico Infangato; VTC = Fanghi Terrigeni Costieri; VB = Fanghi Batiali; Excl = specie caratteristica esclusiva; Pr = specie caratteristica preferenziale. Habitus (**H**): e = epifaunale; s = seminfaunale; i = infaunale; v = vagile; sd = sedentaria; ss = sessile; eb = epibissata; sb = seminfaunale bissata; p = planctonica; perf = perforatrice legno. Trofismo (**T**): O = omnivora; E = erbivora; DT = detritivora; DP = depositivora; SP = sospensivora; CR = carnivora; P = parassita; N = necrofaga; f = filtratrice. Distribuzione stratigrafica (**DS**): Paleoc = Paleocene; Olig = Oligocene; M = Miocene; Pl = Pliocene; Pleis = Pleistocene; Ol = Olocene.

Tab. 1. + = extinct species; (+) = species disappeared in the Mediterranean Sea; ?(+) = species disappeared in the Mediterranean Sea but doubtfully extant; = ___ taxon of warm, subtropical and tropical waters; = ___ eurythermal taxon. RM = hand-picked species. Zone (**P**): Sop = supralittoral; m = mediolittoral; I = infralittoral; **I** = mainly infralittoral; C = circalittoral; **C** = mainly circalittoral; B = bathyal. Substrate (**S**): S = sand; F = mud; D = debris; R = rocky; c = coralligenous. Biocoenosis (**B**): SFBC = well-sorted fine sands; SFS = shallow water fine sands; SVMC = muddy sands in sheltered waters; SGCF = coarse sands and gravels under the influence of bottom currents; DC = coastal detritic bottom; DE = muddy detritic bottom; VTC = coastal terrigenous muds; VB = bathyal muds; Excl = exclusive species; Pr = preferential species. Habitus (**H**): e = epifaunal; s = semi-infaunal; i = infaunal; v = vagile; sd = sedentary; ss = sessile; eb = epibyssate; sb = endobyssate; p = planktonic; perf = wood borer. Trophism (**T**): O = omnivore; E = herbivore; DT = detritivore; DP = depositivore; SP = suspension feeder; CR = carnivorous; P = parasite; N = necrofagous; f = filter feeder. Stratigraphic distribution (**DS**): Paleoc = Paleocene; Olig = Oligocene; M = Miocene; Pl = Pliocene; Pleis = Pleistocene; Ol = Holocene.

Composizione e significato della fauna

I bivalvi sono rappresentati dal maggior numero (82%) di resti, mentre gli scafopodi costituiscono una frazione minima, pari all'1% (**Tab. 1, Fig. 1A**). Come si può desumere dalla **Tab. 1**, le specie del piano circalitorale sono dominanti (36%); risultano ben rappresentate anche le specie euribate (24%) e quelle a distribuzione infra-circalitorale (22%). Sono meno numerose le specie indicative del piano infralitorale (17%) e sono presenti con una percentuale trascurabile (1%) le specie del circalitorale-batiale (**Fig. 1B**). Le specie note per i piani soprali-

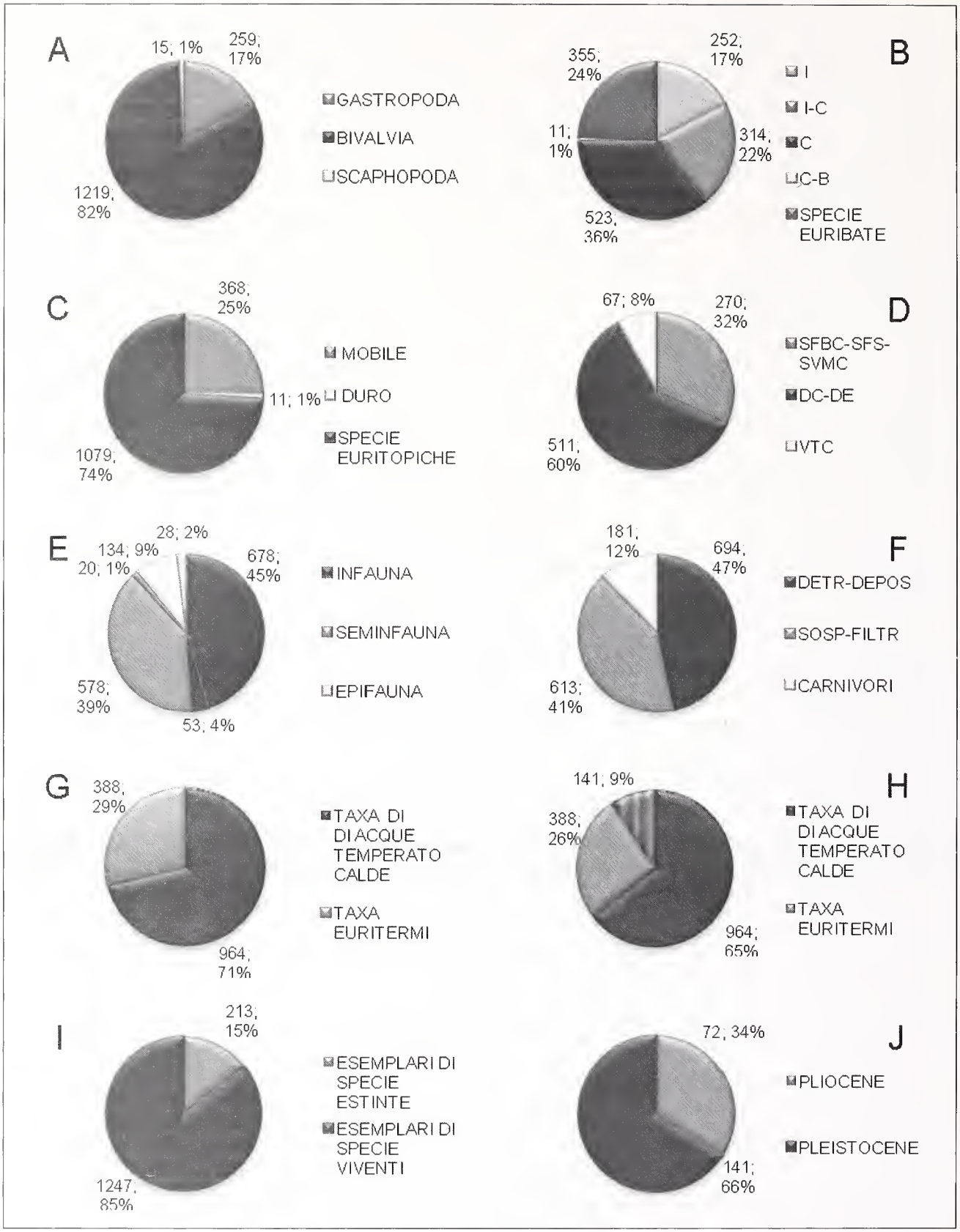

Fig. 1. A. Classi di molluschi presenti. **B.** Distribuzione delle specie nei piani bentonici. **C.** Distribuzione delle specie nei vari tipi di substrato. **D.** Specie caratteristiche, esclusive e preferenziali, delle biocenosi (la percentuale, del tutto trascurabile, dei tre esemplari appartenenti a due specie preferenziali della biocenosi VB non è riportata). **E.** Habitus degli organismi esaminati (le porzioni di minor ampiezza, all'interno dei tre settori, includono le forme sessili). **F.** Trofismo degli organismi esaminati (la percentuale, del tutto trascurabile, di un esemplare erbivoro e di un esemplare omnivoro non è riportata). **G, H.** Indici paleoclimatici. **I.** Esemplari di specie viventi ed estinte. **J.** Esemplari di specie estinte nel Pliocene e nel Pleistocene.

Fig. 1. A. Mollusc classes in the assemblage. **B.** Species distribution in the benthic zones. **C.** Species distribution according to different types of substrate. **D.** Exclusive and preferential species of Biocoenosis (the negligible percentage of 3 specimens, belonging to two preferential VB species is not reported). **E.** Habitus (the smaller portions, within the main sectors, include sessile forms). **F.** Trophism (the negligible percentage of two specimens, one herbivore, the other omnivore, is not reported). **G, H.** Palaeoclimatic indices. **I.** Specimens of living and extinct species. **J.** Specimens extinct during the Pliocene and the Pleistocene.

torale e mesolitorale sono state conteggiate come se fossero presenti a partire dall'infralitorale. Le specie euritopiche sono rappresentate dal maggior numero (74%) di individui (**Tab. 1**, **Fig. 1C**), mentre circa ¼ degli esemplari è indicativo di substrato mobile; è del tutto trascurabile la percentuale (1%) degli esemplari di specie di substrato duro. Per quanto riguarda l'afferenza alle biocenosi di Pérès & Picard (1964), gli esemplari delle specie caratteristiche, esclusive e preferenziali, di DC-DE sono stati conteggiati insieme, così come quelli delle specie SFBC-SFS-SVMC (solo *Donax* cfr. *trunculus*, con un unico esemplare, è esclusivo delle SFS e solo *Paphia aurea*, con solo due esemplari, è preferenziale delle SVMC). Le specie indicative delle biocenosi DC e DE (DC-DE) sono rappresentate dal maggior numero di individui (60%). Sono ben rappresentate (32%) anche le specie afferenti alla biocenosi SFBC, mentre è presente solo una piccola percentuale (8%) di individui di specie legate alla biocenosi VTC. Solo due specie, *Fusinus rostratus* e *Linuatula subauriculata*, risultano essere preferenziali VB (**Tab. 1**, **Fig. 1 D**). Non sono stati conteggiati i 17 esemplari di *Anadara diluvii* perché questa specie è considerata caratteristica preferenziale sia della biocenosi DC (Porcheddu & al., 1997) sia dei VTC (Di Geronimo & Costa, 1980).

I taxa infaunali (49%) e seminfaunali (40%), prevalentemente vagili o sedentari, sono rappresentati dal maggior numero di esemplari; *Corbula gibba* è l'unica specie infaunale sessile e *Anadara diluvii* ed *Ambrogia mytiloides* sono le sole specie seminfaunali, entrambe bissate. I taxa epifaunali, anch'essi prevalentemente vagili o sedentari, sono poco rappresentati, costituendo solo l'11% dell'associazione (**Tab. 1**, **Fig. 1 E**).

Dal punto di vista trofico, gli esemplari delle specie detritivore e depositivore sono stati conteggiati come un unico gruppo, così come quelli delle specie filtratrici e sospensivore. Detritivori e depositivori sono rappresentati dal maggior numero di individui (47%), ma sono ben rappresentati (41%) anche i filtratori, mentre l'unica specie sospensivora è *Calyptraea chinensis* con un solo individuo. I carnivori, nei quali sono stati inclusi predatori, necrofagi e parassiti, sono meno numerosi (12%) e quasi tutti gasteropodi (l'unica specie di bivalvi carnivora è *Cuspidaria cuspidata*, con un unico esemplare). È del tutto trascurabile la presenza di un esemplare erbivoro di *Clelaudella miliaris* e di un esemplare omnivoro di *Gibbula* sp. (**Tab. 1**, **Fig. 1F**).

Per il 9% degli esemplari esaminati, non si hanno indicazioni paleoclimatiche, poiché mancano dati in letteratura. È noto, tuttavia, che la malacofauna pliocenica mediterranea è strettamente affine a quella attualmente vivente lungo le coste dell'Africa Nord-Occidentale (Raffi & al., 1985; Raffi & Monegatti, 1993; Tabanelli, 2008; Chirli & Micali, 2011). In effetti, il 65 % degli individui isolati appartiene a taxa indicativi di acque da temperate a tropicali (**Tab. 1**, **Fig. 1 H**) ed è ipotizzabile che quelle specie per le quali non si hanno indicazioni paleoclimatiche, possano essere rappresentate da forme euriterme o temperato-tropicali. Riguardo ad *Acanthocardia echinata* e *Dosinia lupinus*, si precisa che queste specie vivono sia in acque fredde, con esemplari a conchiglia spessa, sia in acque calde, con esemplari a conchiglia sottile (Sami & Taviani, 1996). A "Le Conchiglie", queste specie sono presenti con gusci molto sottili, spesso frammentati, e possono pertanto essere riferite ad esemplari viventi in acque calde. Tenendo conto solo degli esemplari di cui si hanno informazioni paleoclimatiche, prevalgono nettamente (71%) quelli di acque temperato-calde, rispetto al 29% di euritermi (**Tab. 1**, **Fig. 1 G**).

La grande maggioranza degli esemplari esaminati (85%) appartiene a specie tuttora viventi (**Tab. 1**, **Fig. 1 I**). Sono più numerosi gli esemplari di specie estinte nel Pleistocene (66%) rispetto a quelli (34%) di specie estinte nel Pliocene (**Tab. 1**, **Fig. 1 J**).

Oltre ai molluschi, nel campione esaminato sono presenti briozoi, anellidi, echinidi, crostacei (tra cui, ostracodi e *Balanus* sp.), otoliti, ittiodontoliti e foraminiferi bentonici (**Fig. 4J**).

Discussione

Nell'associazione dominano le specie che hanno la massima diffusione nel circalitorale, ma sono ben rappresentate le specie sia euribate, sia comuni ai piani infra- e circalitorale. Ciò, assieme alla presenza, se pur ridotta, delle specie tipiche dell'infralitorale, fa dedurre che l'associazione in esame si sia formata in un'area di transizione fra il piano infralitorale e quello circalitorale (**Fig. 1B**).

Prevalgono nettamente le specie euritopiche ed è presente una notevole porzione di organismi di substrato mobile. Comunque, la presenza minima di specie di substrato duro (**Fig. 1C**) fa supporre che gli organismi esaminati vivessero in fondali sabbioso-fangosi con presenza di detriti.

La prevalenza di specie afferenti alle biocenosi DC e DE e l'abbondanza di specie esclusive o preferenziali della biocenosi SFBC (**Fig. 1D**), suggerisce che la malacofauna esaminata corrisponda ad un ecotono fra le paleobiocenosi SFBC e DC-DE. Questa interpretazione è in buon accordo con il tipo di substrato riscontrato, di natura sabbioso-pelitica con detriti e con l'indicazione batimetrica sopra riportata.

I taxa vagili e sedentari sono maggiormente rappresentati, sia nell'infauna e seminfauna (nettamente prevalenti), sia nell'epifauna, evidentemente perché favoriti rispetto alle forme sessili (**Fig. 1E**). Sono maggiormente rappresentati i detritivori/depositivori ed i filtratori, mentre la modesta percentuale di carnivori è costituita, quasi esclusivamente, da gasteropodi (**Fig. 1F**).

Oltre la metà degli esemplari esaminati appartiene a specie indicative di acque calde o temperate (**Figg. 1G**, **H**). Si deduce che la malacofauna studiata vivesse in un mare caldo, subtropicale.

La maggior parte delle specie esaminate è tuttora vivente (**Fig. 1 I**); tra quelle estinte, prevalgono nettamente quelle scomparse nel Pleistocene (**Fig. 1 J**); questo dato è spiegabile con l'indicazione paleoclimatica so-

pracitata ed è imputabile al periodico verificarsi di lunghi intervalli glaciali, nel Quaternario (Hays & al., 1976). La stessa indicazione paleoclimatica è ulteriormente confermata dalla presenza di *Venus foliaceolamellosa* e *Pelecyora gigas*, raccolta solo manualmente, entrambe non più presenti in Mediterraneo a partire dal Piacenziano medio, in seguito al primo processo di raffreddamento climatico verificatosi intorno a 3.2 -3.0 M.a. (Raffi & Monegatti, 1993; Ferrero & al., 1997).
La malacofauna esaminata permette di delimitare ulteriormente l'inquadramento stratigrafico della Formazione di Monte Adone, tra il Piacenziano inferiore ed il Piacenziano medio. In merito, va segnalata la presenza di *Bathytoma cataphracta*, *Bela nitida*, *Eulimella subalpina* e *Turbonilla pliopupoides*, tutte estinte nel Pliocene medio (Pavia, 1975) (**Fig. 5**).

Sistematica

Classe Gastropoda Cuvier, 1795
Famiglia Rissoidae Gray, 1847
Genere *Pusillina* Monterosato, 1884
Pusillina inconspicua (Alder, 1844)
(Fig. 2A, B)

Rissoa inconspicua Alder, 1844: p. 327, figg. 6-7 (*fide* Chirli, 2006).
Turboella inconspicua - Nordsieck, 1968: p. 53, tav. 8, fig. 28.34.
Pusillina cf. *inconspicua* - Cavallo & Repetto, 1992: p. 54, fig. 082.
Pusillina inconspicua - Cossignani & al., 1992: fig. 077.
Pusillina inconspicua - Arduino & al., 1995: p. 43.
Pusillina inconspicua - Giannuzzi – Savelli & al., 1996: figg. 267–269.
Pusillina inconspicua - Chirli, 2006: p. 45, tav. 21, figg. 5–9.
Pusillina inconspicua - Brunetti & Vecchi, 2007: p. 59, tav. 3, fig. 4.

Osservazioni

È una specie piuttosto variabile, soprattutto per la distribuzione delle costicelle assiali (Chirli, 2006); negli esemplari esaminati esse sono presenti solo negli ultimi 2-3 giri.

Famiglia Conidae Fleming, 1822
Genere *Conus* Linnaeus, 1758
Conus sp. juv.
(Fig. 2C, D)

Osservazioni

In base alle ridotte dimensioni e alla spira, notevolmente slanciata, si ritiene che l'esemplare esaminato sia uno stato giovanile di *Conus antidiluvianus* Bruguière, 1792, frequente nei livelli campionati.

Famiglia Mangeliidae P. Fischer, 1883
Genere *Bela* Leach in Gray, 1847
Bela nitida Pavia, 1975
(Fig. 2E, F)

Bela nitida Pavia, 1975: p. 148, tav. 8, figg. 17–20.
Bela nitida - Cavallo & Repetto, 1992: p. 140, fig. 377.
Bela nitida - Chirli, 1997: p. 53, tav. 15, fig. 1.
Bela nitida - Chirli & Richard, 2008 : p. 66, tav. 13, fig. 3.

Osservazioni

È una specie molto variabile, come risulta dalle illustrazioni fornite dai vari autori riportati in sinonimia. Gli esemplari esaminati si avvicinano maggiormente a quelle di Pavia (1975) e di Cavallo & Repetto (1992).

Famiglia Architectonicidae Gray, 1850
Genere *Pseudomalaxis* P. Fischer, 1885
Pseudomalaxis aldrovandii (Foresti, 1868)
(Fig. 2G)

Solarium Aldrovandii Foresti, 1868: p. 87, tav. 2, figg. 17-20.
Pseudomalaxis zancleus Philippi - Rindone, 1986: p. 300, fig. 1.
Pseudomalaxis aldrovandii - Ricordi, 1991: pp. 22–24.
Pseudomalaxis aldrovaudii - Bogi & al., 2002: p. 35, figg. 23–24.
Pseudomalaxis aldrovandii - Sosso & Dell'Angelo, 2010: pp. 51, 66.

Osservazioni

Rindone (1986) raffigura e descrive la specie *P. zancleus* Philippi, 1844 come caratterizzata da "un doppio cordone suturale e periferico"; al contrario, Bogi et al. (2002) sostengono che *P. zancleus* si distingue da *P. aldrovandii* "assai facilmente per avere un solo cingolo decorrente sul bordo esterno". Anche la descrizione originale di *P. aldrovandii*, riportata da Ricordi (1991), parla di "*anfractibus bicarinatis*". In base a tale descrizione, e in accordo con Bogi et al. (2002), si ritiene che il frammento esaminato, presentando un doppio cordone marginale, sia attribuibile a *P. aldrovandii*. Come indicazione ecologica possiamo tenere conto di quanto riportato in Ardovini & Cossignani (1999), secondo cui gli Architectonicidae si nutrono di scleractiniari e anemoni.

Famiglia Pyramidellidae Gray, 1840
Genere *Chrysallida* Carpenter, 1857
Chrysallida stefauisi (Jeffreys, 1869)
(Fig. 2H, I)

Rissoa Stephauisi Jeffreys, 1869: p. 208.
Pyrgulina pygmaea var. *postica* Sacco - Sacco, 1892: p. 651, tav. 1, fig. 113.
Chrysallida stefanisi - Cecalupo, 1986: p. 263.
Chrysallida stefanisi - Cavallo & Repetto, 1992: p. 154, fig. 427.
Chrysallida stefanisi - Cossignani & al., 1992: fig. 194.
Chrysallida stefanisi - Ardovini & Cossignani, 1999: p. 78.
Chrysallida stefanisi - Gruppo Malacol. Livornese, 2003: p. 24.

Osservazioni

Gli esemplari osservati sono del tutto simili a quelli raffigurati dagli autori citati nella sinonimia, tra i quali solo Cavallo & Repetto (1992) illustrano forme fossili. Gli esemplari che riportano in fig. 427b, riferibili alla forma

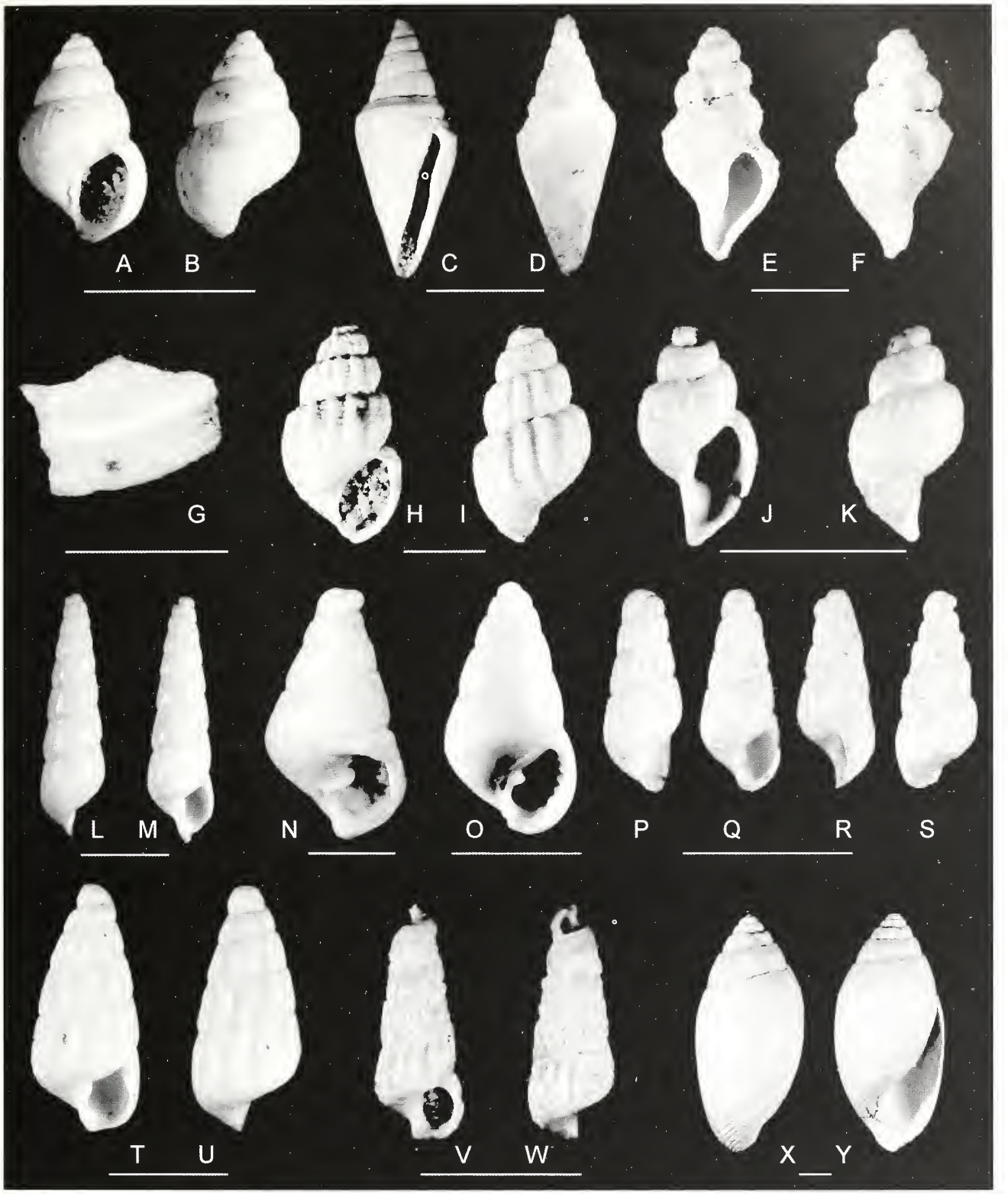

Fig. 2. A, B. *Pusillina inconspicua* (Alder, 1844). **C, D.** *Conus* sp. juv. **E, F.** *Bela nitida* Pavia, 1975. **G.** *Pseudomalaxis aldrocvandii* (Foresti, 1868). **H, I.** *Chrysallida stefanisi* (Jeffreys, 1869). **J, K.** *Chrysallida* sp. **L, M.** *Eulimella subalpina* (Sacco, 1892). **N.** *Odostomia acuta* Jeffreys, 1848. **O.** *O. conoidea* (Brocchi, 1814). **P-S.** *Turbonilla pliocostellatoides* Sacco, 1892. **T, U.** *T. pliopupoides* (Sacco, 1892). **V, W.** *T.* cfr. *postacuticostata* Sacco, 1892. **X, Y.** *Acteon semistriatus* (Férussac, 1822). Linee di scala = 1 mm.

Fig. 2. A, B. *Pusillina inconspicua* (Alder, 1844). **C, D.** *Conus* sp. juv. **E, F.** *Bela nitida* Pavia, 1975. **G.** *Pseudomalaxis aldrocvandii* (Foresti, 1868). **H, I.** *Chrysallida stefanisi* (Jeffreys, 1869). **J, K.** *Chrysallida* sp. **L, M.** *Eulimella subalpina* (Sacco, 1892). **N.** *Odostomia acuta* Jeffreys, 1848. **O.** *O. conoidea* (Brocchi, 1814). **P-S.** *Turbonilla pliocostellatoides* Sacco, 1892. **T, U.** *T. pliopupoides* (Sacco, 1892). **V, W.** *T.* cfr. *postacuticostata* Sacco, 1892. **X, Y.** *Acteon semistriatus* (Férussac, 1822). Scale bars = 1 mm.

postica Sacco (1892), sono i più simili agli esemplari esaminati. In base alle considerazioni riportate da Cecalupo (1986), si ritiene che *C. pygmaea* e *Rissoa costulata* (Wood, 1848) siano sinonimi di *C. stefanisi*. Anche alcune segnalazioni plioceniche di *C. subtypica* (Sacco, 1892) potrebbero trattarsi di *C. jeffreysii* (A. Bell, 1872) ritenuta una varietà di *C. stefanisi* da Wood (1874; in Chirli & Micali, 2011).

Chrysallida sp.
(Fig. 2J, K)

Osservazioni

Si ritiene che l'esemplare esaminato sia da attribuire ad una nuova specie, rinvenuta da Micali (com. pers., 30.10.2010) a Rio Torsero. La località fossilifera di Rio Torsero ricade nelle Biozone MPl 3-MPl 4 (Sosso & Dell'Angelo, 2010), tra 4.5 e 3.6 M.a. (Spaak, 1983).

Genere *Eulimella* Forbes & M'Andrew, 1846
Eulimella subalpina (Sacco, 1892)
(Fig. 2L, M)

Anisocycla subalpina Sacco, 1892: p. 639, tav. 2, figg. 26–29.
Anisocycla subalpina - Ferrero Mortara & al., 1984: p. 77, tav. 11, fig. 12.
?*Eulimella subalpina* - Pavia, 1975: p. 160, tav. 11, figg. 4–8.
?*Eulimella subalpina* - Cavallo & Repetto, 1992: p. 156, fig. 438.
Eulimella subalpina - Chirli & Micali, 2011: p. 17, tav. 4, figg. 9–15.

Osservazioni

Gli esemplari esaminati risultano essere, tra le illustrazioni riportate in sinonimia, maggiormente simili, dal punto di vista morfologico, a quelle di Sacco (1892) e a quelle di Chirli & Micali (2011) in quanto mancano di evidenti coste assiali. Tale ornamentazione è invece presente negli esemplari illustrati da Cavallo & Repetto (1992) e da Pavia (1975). Chirli & Micali (2011), che segnalano questa specie, per la prima volta, nel Pliocene della Toscana, la indicano presente anche nel Pliocene del Piemonte, della Liguria e del Lazio; con questo lavoro, se ne segnala la presenza anche in Emilia.

Genere *Odostomia* Fleming, 1813
Odostomia acuta Jeffreys, 1848
(Fig. 2N)

Odostomia acuta Jeffreys, 1848: pp. 330, 338.
Odontostomia acuta - Sacco, 1892: p. 619, tav. 1, figg. 78–81.
Ptychostomon acutum - Kobelt, 1905: p. 80, tav. 67, fig. 17.
Odostomia acuta - Warén, 1980: p. 37, tav. 6, figg. 23–24.
Odostomia acuta - Terreni, 1981: tav. 7, fig. 12.
Odontostomia acuta - Ferrero Mortara & al., 1984: p. 72, tav. 10, fig. 10.
Odostomia acuta - Aartsen, 1987: p. 8, fig. 15.
Odostomia acuta - Cavallo & Repetto, 1992: p. 158, fig. 443.
Odostomia acuta - Cossignani & al., 1992: fig. 209.
Odostomia acuta - Repetto & Lacroce, 2003: p. 200, tav. 1, fig. 7.
Odostomia acuta - Solustri & Micali, 2004: p. 66, fig. 5e.
Odostomia acuta - Chirli & Micali, 2011: p. 49, tav. 16, figg. 6–11.

Osservazioni

Conchiglia con protoconca con asse inclinato di circa 90° rispetto a quello della teleoconca, di forma elicoide con nucleo sporgente, di tipo "A2" secondo Chirli & Micali (2011). Guscio liscio con linee di accrescimento approssimativamente verticali; giri ben arrotondati con cospicuo ombelico; labbro esterno privo di denti; dente columellare acuto e sporgente. Solustri & Micali (2004) indicano *Odostomia acuta* parassita di briozoi e del polichete tubicolo *Myxicola infundibulum*.

Odostomia conoidea (Brocchi, 1814)
(Fig. 2O)

Turbo conoideus Brocchi, 1814: p. 660, tav. 16, fig. 2.
Odontostomia conoidea - Sacco, 1892: p. 615, tav. 1, figg. 66–70.
Odontostomia conoidea - Sacco, 1904: p. 108, tav. 24, figg. 7–8.
Ptychostomon conoideum - Kobelt, 1905: p. 78, tav. 66, figg. 12–15.
Odostomia conoidea - Pavia, 1975: p. 158, tav. 10, figg. 9–13.
Odostomia conoidea - Terreni, 1981: tav. 7, fig. 11.
Odostomia conoidea - Aartsen, 1987: p. 7, fig. 12.
Odostomia conoidea - Cavallo & Repetto, 1992: p. 160, fig. 454.
Odostomia conoidea - Cossignani & al., 1992: fig. 218.
Odostomia conoidea - Arduino & al., 1995: p. 109.
Odostomia conoidea - Solustri & Micali, 2004: p. 66, fig. 5f.
Odostomia conoidea - Ferrero & al., 2005: tav. 1, fig. 4.
Odostomia conoidea - Chirli & Richard, 2008: p. 76, tav. 15, figg. 4–5.
Odostomia conoidea - Sosso & Dell'Angelo, 2010: pp. 52, 67.
Odostomia conoidea - Chirli & Micali, 2011: p. 53, tav. 18, figg. 1–7.

Osservazioni

Conchiglia con protoconca elicoidale a nucleo parzialmente infossato nel primo giro e inclinato di circa 90° rispetto all'asse della spira, di tipo "A2" secondo Chirli & Micali (2011). Guscio liscio con linee di accrescimento verticali, labbro esterno internamente plicato. È parassita di stelle marine (Solustri & Micali, 2004).

Genere *Turbonilla* Risso, 1826
Turbonilla pliocostellatoides Sacco, 1892
(Fig. 2P-S)

Turbonilla pliocostellatoides Sacco, 1892: p. 659, tav. 2, fig. 64.
Turbonilla pliocostellatoides - Pavia, 1975: p. 165, tav. 12, figg, 1, 4–5.
Turbonilla pliocostellatoides - Ferrero Mortara & al., 1984: p. 81, tav. 12, fig. 3.
Turbonilla pliocostellatoides - Cavallo & Repetto, 1992: p. 162, fig. 463.
Turbonilla pliocostellatoides - Chirli & Micali, 2011: p. 91, tav. 33, figg. 1–6.

Osservazioni

Conchiglia di forma subcilindrica. Protoconca di tipo "A2" secondo Chirli & Micali (2011) con nucleo disposto a circa 90° rispetto all'asse della spira. Giri legger-

mente convessi con coste assiali e sutura profonda. Chirli & Micali (2011) segnalano questa specie nel Pliocene del Piemonte, Liguria, Toscana e Lazio. Se ne segnala la presenza anche in Emilia.

Turbonilla pliopupoides (Sacco, 1892)
(Fig. 2T, U)

Pyrgolampros? pliopupoides Sacco, 1892: p. 674, tav. 2, fig. 106.
Turbonilla pliopupoides - Pavia, 1975: p. 165, tav. 11, figg. 9–10.
Pyrgolampros ? pliopupoides - Ferrero Mortara & al., 1984: p. 84, tav. 12, fig. 8.
Turbonilla pliopupoides - Cavallo & Repetto, 1992: p. 162, fig. 465.
Turbonilla pliopupoides - Chirli & Micali, 2011: p. 94, tav. 34, figg. 1–6.

Osservazioni

Gli esemplari esaminati presentano una protoconca la cui spira è inclinata di circa 130° rispetto all'asse della conchiglia, con nucleo infossato per circa metà nella teleoconca, di tipo "B" secondo Chirli & Micali (2011) e corrispondono alla descrizione data da Pavia (1975): "giri un poco più larghi, ricordando in tal senso la miocenica *T. (P.) miopupoides* (Sacco), ma ugualmente piani con fascia subsuturale rigonfia". Pavia ha rinvenuto questa specie nel Pliocene inferiore e medio piemontese e ligure, anche a Rio Torsero; in questa stessa località, anche Sosso & Dell'Angelo (2010) hanno rinvenuto questa specie che, tuttavia, ritengono (*fide* Crovato & Micali, 1992) *Pyrgolampros? pliopupoides* Sacco, 1892 sinonimo di *Turbonilla compressa* (Jeffreys, 1884). In effetti, Crovato & Micali (1992) sostenevano tale sinonimia; tuttavia, secondo Micali (com. pers., 5.3.2012) "*T. compressa* (ora si usa il nome di *T. amoena*) differisce da *T. pliopupoides* per la protoconca più piccola e più immersa nel primo giro di teleoconca, l'accrescimento più veloce dei giri, le coste meno rilevate e gli interspazi meno profondi." Nonostante la somiglianza tra le due specie sia notevole, alla luce delle differenze rilevate, si preferisce trattarle come specie distinte.

Turbonilla cfr. ***postacuticostata*** Sacco, 1892
(Fig. 2V, W)

Turbonilla postacuticostata Sacco, 1892: p. 658.
Turbonilla postacuticostata - Cavallo & Repetto, 1992: p. 162, fig. 466.
Turbonilla postacuticostata - Arduino & al., 1995: p. 112.
Turbonilla postacuticostata - Sosso & Dell'Angelo, 2010: pp. 53, 68.

Osservazioni

È una specie dotata di una conchiglia subcilindrica, con protoconca di tipo "A2" (*sensu* Chirli & Micali, 2011). Le coste assiali ortocline sono più sottili degli interspazi e si interrompono bruscamente alla base dell'ultimo giro. Gli esemplari esaminati, incompleti, sono stati avvicinati a *T. postacuticostata* in base alla forma delle coste ed alla chiusura degli interspazi alla periferia abbastanza caratteristiche.

Famiglia Acteonidae d'Orbigny, 1843
Genere *Acteon* Montfort, 1810
Acteon semistriatus (Férussac, 1822)
(Fig. 2X, Y)

Tornatella inflata Férussac, 1822: p. 108 (*fide* Sacco, 1897).
Actaeon semistriatus - Sacco, 1897: p. 33, tav. 3, figg. 21-32.
Acteon semistriatus - Cavallo & Repetto, 1992: p. 164, fig. 469.
Acteon semistriatus - Chirli & Richard, 2008: p. 79, tav. 16, figg. 1-2.

Osservazioni

Questa specie è segnalata da Chirli & Richard (2008) e da Sacco (1897) a partire dal Miocene. Ragaini & Bernieri (2007: p. 149, tab. 1) la indicano come esclusiva del Pliocene.

Famiglia Retusidae Thiele, 1925
Genere *Cylichnina* Monterosato, 1884
Cylichnina pliosimplex Sacco, 1897
(Fig. 3A, B)

Cylichnina pliosimplex Sacco, 1897: p. 51, tav. 4, figg. 15-18.
Cylichnina pliosimplex - Ferrero Mortara & al., 1984: p. 288, tav. 52, fig. 10.
Cylichnina pliosimplex - Chirli, 2013: p. 53, tav. 12, figg. 1-6.

Osservazioni

Questa specie è stata indicata da Sacco (1897) come "abbondante" nel Piacenziano di Villalvernia ed è stata segnalata, per la prima volta, nel Pliocene toscano, da Chirli (2013). Con questo lavoro, se ne segnala la presenza anche in Emilia.

Famiglia Philinidae Gray, 1850
Genere *Philine* Ascanius, 1772
Philine scabra (Müller, 1784)
(Fig. 3C)

Bulla scabra Müller, 1784: p. 41, tav. 71, figg. 11-12.
Hermania scabra - Sacco, 1897: p. 54, tav. 4, fig. 42.
Philine scabra - Cavallo & Repetto, 1992: p. 168, fig. 486.
Philine scabra - Cossignani & al., 1992: fig. 235.
Philine scabra - Arduino & al., 1995: p. 119.
Philine scabra - Gruppo Malacol. Livornese, 2004 (b): p. 30, fig. 5.
Philine scabra - Chirli & Richard, 2008: p. 82, tav. 16, fig. 8.
Philine scabra - Sosso & Dell'Angelo, 2010: pp. 54, 68.

Osservazioni

I frammenti esaminati comprendono parti del labbro esterno, tipicamente sfrangiato, con la caratteristica ornamentazione che contraddistingue questa specie. *Philine scabra*, distribuita dal punto di vista stratigrafico sin dal Miocene, è segnalata, in Italia, solo a partire dal Pliocene (Chirli & Richard, 2008).

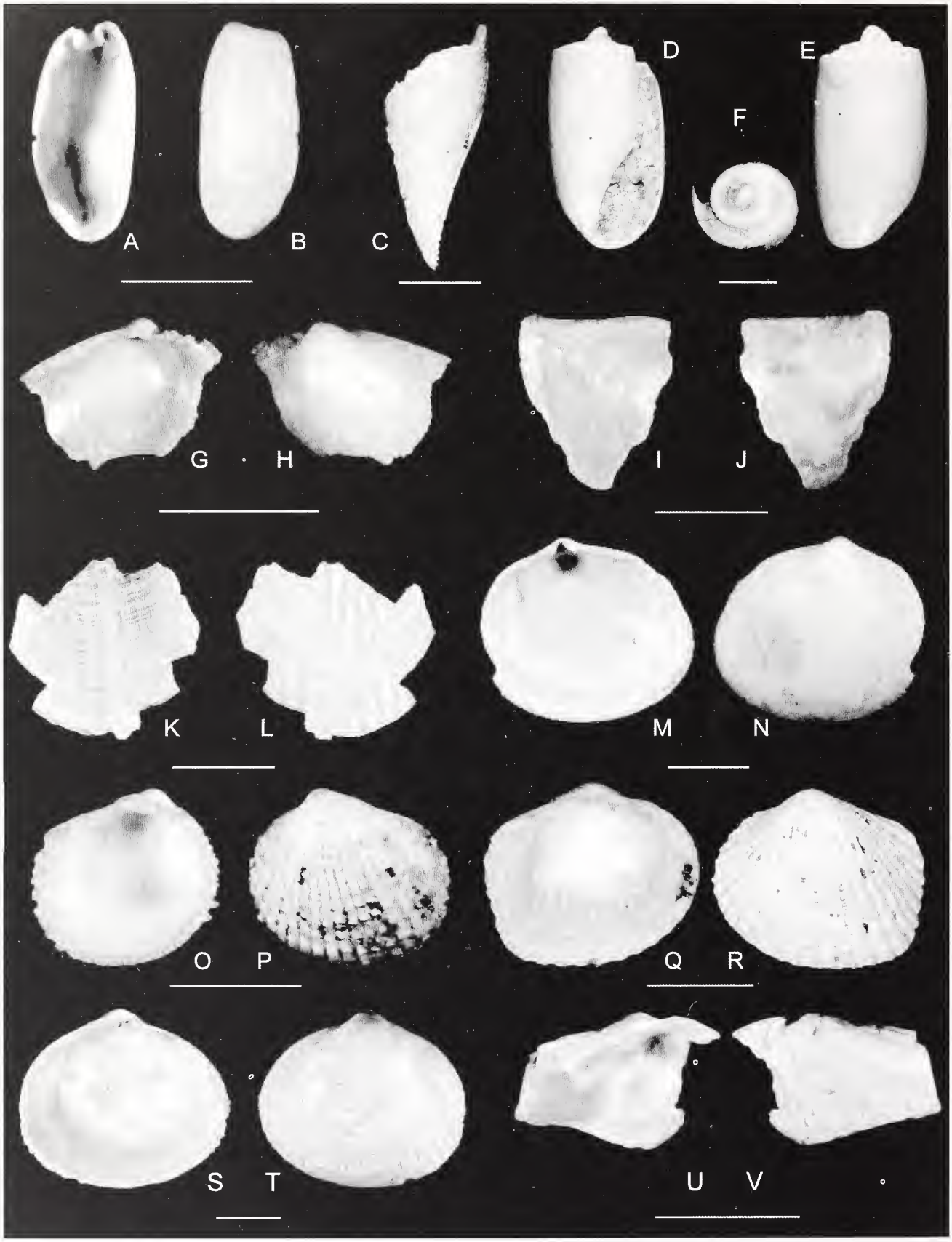

Fig. 3. A, B. *Cylichnina pliosimplex* Sacco, 1897. **C.** *Philine scabra* (Müller, 1784). **D-F.** *Acteocina knockeri* (Smith, 1871). **G, H.** *Musculus* cfr. *discors* (Linné, 1767). **I, J.** *Pteria phalenacea* (Lamarck, 1819). **K, L.** *Limatula subauriculata* (Montagu, 1808). **M, N.** *Mysella* sp. **O, P.** *Parvicardium vroomi pliopapillosa* (Sacco, 1899). **Q, R.** *P. scabrum* (Philippi, 1844). **S, T.** *Laevicardium subturgidum millasiense* (Fontannes, 1881). **U, V.** *Donacilla cornea* (Poli, 1791). Linee di scala = 1 mm.

Fig. 3. A, B. *Cylichnina pliosimplex* Sacco, 1897. **C.** *Philine scabra* (Müller, 1784). **D-F.** *Acteocina knockeri* (Smith, 1871). **G, H.** *Musculus* cfr. *discors* (Linné, 1767). **I, J.** *Pteria phalenacea* (Lamarck, 1819). **K, L.** *Limatula subauriculata* (Montagu, 1808). **M, N.** *Mysella* sp. **O, P.** *Parvicardium vroomi pliopapillosa* (Sacco, 1899). **Q, R.** *P. scabrum* (Philippi, 1844). **S, T.** *Laevicardium subturgidum millasiense* (Fontannes, 1881). **U, V.** *Donacilla cornea* (Poli, 1791). Scale bars = 1 mm.

Famiglia Cylichnidae Adams H. & A., 1854
Genere *Acteocina* Gray, 1847
Acteocina knockeri (Smith, 1871)
(Fig. 3 D-F)

Voluta spirata Brocchi, 1814: p. 644, tav. 15, fig. 12.
Tornatina knockeri Smith, 1871: p. 738, tav. 75, fig. 30.
Tornatina spirata - Sacco, 1897: p. 38, tav. 3, figg. 58–62.
Acteocina spirata - Aimassi & Ferrero Mortara, 1983: tav. 2, fig. 2.
Utriculastra knockeri - Hoenselaar & Gulden, 1991: p. 57, figg. 1-2.
Acteocina knockeri - Gruppo Malacol. Livornese, 2004 (a): p. 64.
Acteocina knockeri - Ragaini & Bernieri, 2007: p. 153, fig. 3i.

Osservazioni

Questa specie è stata segnalata, per il Pliocene del Mediterraneo, da Ragaini & Bernieri (2007). Oggi è nota solo lungo le coste tunisine (Hoenselaar & Gulden, 1991).

Famiglia Creseidae Rampal, 1973
Genere *Styliola* Gray, 1847
Styliola subula (Quoy & Gaimard, 1827)

Cleodora subula Quoy & Gaimard, 1827: p. 233, tav. 8D, figg. 1-3 (*fide* Tesch, 1913).
Styliola subula - Di Geronimo, 1970: p. 81, tav. 5, fig. 2.
Styliola subula - Tedeschi & al., 1988: tav. 2, fig. 8.
Styliola subula - Cavallo & Repetto, 1992: p. 170, fig. 497.
Styliola subula - Cossignani & al., 1992: fig. 245.
Styola subula - Arduino & al., 1995: p. 122.
Styliola subula - Janssen, 1995: p. 29, tav. 2, figg. 1–2.

Osservazioni

Styliola subula è l'unica specie pelagica presente nell'associazione. In particolare, questa specie vive nella zona mesopelagica (Tedeschi & al., 1988) ed è comune nella parte meridionale del Mediterraneo, nell'Oceano Atlantico, Indiano e Pacifico (Di Geronimo, 1970).

Classe Bivalvia Linnaeus, 1758
Famiglia Mytilidae Rafinesque, 1815
Genere *Musculus* Röding, 1798
Musculus cfr. ***discors*** (Linné, 1767)
(Fig. 3G, H)

Mytilus discors Linné, 1767: p. 1159.
Modiola discors - Hörnes, 1870: p. 349, tav. 45, fig. 5.
Musculus discors - Tebble, 1966: p. 46, tav. 1, fig. k.
Musculus discors - Nordsieck, 1969: p. 35, tav. 5, fig. 23.00.
Musculus discors - Arduino & al., 1995: p. 135.

Osservazioni

Tebble (1966) segnala questa specie nella facies a *Corallina officinalis* della biocenosi AP di Pérès & Picard (1964) e ne indica l'ampia distribuzione nei mari attuali, così come Sacco (1898) l'aveva indicata in quelli terziari. Data la fragilità delle sue valve, gli individui esaminati sono estremamente frammentati, come si può vedere dall'illustrazione.

Famiglia Pteriidae Gray, 1847
Genere *Pteria* Scopoli, 1777
Pteria phalenacea (Lamarck, 1819)
(Fig. 3I, J)

Avicula phalaenacea Lamarck, 1819: p. 150.
Avicula hirundo var. *phalaenacea* - Sacco, 1898: p. 23, tav. 6, figg. 9–13.
Pteria phalenacea - Cavallo & Repetto, 1992: p. 184, fig. 544.

Osservazioni

È una specie molto variabile, dal punto di vista morfologico, a seconda delle condizioni ambientali (Sacco, 1898), e molto simile all'attuale *Pteria hirundo* (Linnaeus, 1758).

Famiglia Limidae Rafinesque, 1815
Genere *Limatula* Wood, 1839
Limatula subauriculata (Montagu, 1808)
(Fig. 3K, L)

Pecten subauriculata Montagu, 1808: p. 63, tav. 29, fig. 2.
Limatula cf. *subauriculata* - Sacco, 1898: p. 17, tav. 5, fig. 10.
Limatula subauriculata subauriculata - Nordsieck, 1969: p. 57, tav. 9, fig. 36.10.
Lima subauriculata - Di Geronimo & Panetta, 1973: p. 101, tav. 3, fig. 9.
Limatula subauriculata - Rosso, 1979: tav. 17, fig. 19.
Limatula subauriculata - Ardovini & Cossignani, 1999: p. 92.

Osservazioni

È stato possibile riferire i frammenti esaminati a *Limatula subauriculata* grazie alla caratteristica ornamentazione data da sottili coste distribuite regolarmente; la costa centrale è leggermente più in rilievo e, all'interno della valva, in corrispondenza di essa, si ha un solco più marcato.

Famiglia Montacutidae Clark, 1855
Genere *Mysella* Angas, 1877
Mysella sp.
(Fig. 3M, N)

Osservazioni

Gli esemplari esaminati sono stati attribuiti al genere *Mysella* in base alla cerniera, piuttosto caratteristica; essi differiscono dalle specie riportate dai vari autori soprattutto per la posizione subcentrale dell'umbone.

Famiglia Cardiidae Lamarck, 1809
Genere *Parvicardium* Monterosato, 1884
Parvicardium vroomi pliopapillosa (Sacco, 1899)
(Fig. 3O, P)

Parvicardium transversale var. *pliopapillosa* Sacco, 1899: p. 44, tav. 11, figg. 8-10.
Parvicardium transversale var. *pliopapillosa* - Merlino, 2007: p. 113, tav. 10, fig. 1.

Osservazioni

La valva in esame è assimilabile, dal punto di vista morfologico, a *Parvicardium transversale* var. *pliopapillosa* di Sacco (1899), soprattutto per i caratteri delle coste "*papillis* (*superne squamulosis*) *ornatae*". Nonostante questa specie sia indicata da Sacco (1899) come "straordinariamente abbondante" nel Piacenziano di Villalvernia, sembra che non sia stata citata da altri autori. *Cardium transversale* Deshayes, 1854 è considerato sinonimo dell'attuale *Parvicardium vroomi* Aartsen, Menkhorst & Gittenberger, 1984. *P. vroomi* è segnalato da Ávila (2003) in associazione con l'alga *Halopteris filicina* (Grateloup) Kützing, 1843.

Parvicardium scabrum (Philippi, 1844)
(Fig. 3Q, R)

Cardium nodosum Turton, 1822: p. 186, tav. 13, fig. 8.
Cardium scabrum Philippi, 1844: p. 38, tav. 14, fig. 16.
Parvicardium scabrum - Tebble, 1966: p. 103, figg. 48b, 53 a–b.
Parvicardium nodosum - Nordsieck, 1969: p. 99, tav. 15, fig. 55.05.
Parvicardium roseum (Lamarck) - Spada & Della Bella, 1990: p. 396, tav. 6.
Parvicardium roseum - Cavallo & Repetto, 1992: p. 204, fig. 605.
Parvicardium roseum - Arduino & al., 1995: p. 151.
Parvicardium scabrum - Aartsen & Goud, 2000: p. 179, figg. 25-27, 29.

Osservazioni

Gli esemplari esaminati hanno una caratteristica forma quadrangolare simile a quella di esemplari attuali delle coste italiane (Spada & Della Bella, 1990).

Genere *Laevicardium* Swainson, 1840
Laevicardium subturgidum millasiense
(Fontannes, 1881)
(Fig. 3S, T)

Cardium fragile non Brocchi - Hörnes, 1870: p. 178, tav. 30, fig. 6.
Laevicardium cyprium Brocchi var. *millasiensis* Fontannes, 1879–82: p. 99, tav. 6, fig. 11.
Laevicardium cyprium (Brocchi) - Sacco, 1899: p. 52, tav. 12, figg. 1–3.
Laevicardium homofragile Rossi Ronchetti, 1954: p. 27.
Laevicardium subturgidum millasiense Fontannes - Pavia, 1975: p. 166, tav. 13, fig. 5.
Laevicardium subturgidum millasiense - Cavallo & Repetto, 1992: p. 204, fig. 609.
Laevicardium subturgidum millasiense - Sosso & Dell'Angelo, 2010: pp. 75, 81.

Osservazioni

La sinonimia di questa specie è stata ricostruita da Rossi Ronchetti (1954) che ha istituito la nuova specie *Laevicardium homofragile*. Successivamente, Pavia (1975) ha indicato questa specie come sinonimo di *Laevicardium subturgidum millasiense* Fontannes, 1881.

Famiglia Mesodesmatidae Gray, 1840
Genere *Donacilla* Philippi, 1836
Donacilla cornea (Poli, 1791)
(Fig. 3U, V)

Mactra cornea Poli, 1791: p. 73, tav. 19, figg. 8–11 (*fide* Sacco, 1901).
Donacilla cornea - Sacco, 1901: p. 20, tav. 5, figg. 4–6.
Donacilla cornea - Nordsieck, 1969: p. 140, tav. 20, fig. 80.30.
Donacilla cornea - Pavia, 1975: tav. 13, figg. 2, 7.
Donacilla cornea - Cavallo & Repetto, 1992: p. 208, fig. 621.
Donacilla cornea - Arduino & al., 1995: p. 154.

Osservazioni

La cerniera massiccia, caratteristica della specie in oggetto, ha permesso l'attribuzione degli esemplari esaminati a *Donacilla cornea*.

Famiglia Xylophagidae Purchon, 1941
Genere *Xylophaga* Turton, 1822
Xylophaga dorsalis (Turton, 1819)
(Fig. 4A, B)

Pholas dorsalis Turton, 1819: p. 185 (*fide* Sacco, 1901).
Xylophaga dorsalis - Sacco, 1901: p. 55, tav. 13, figg. 50–53.
Xylophaga dorsalis - Cossignani & al. 1992: fig. 397.

Osservazioni

Data la fragilità di questa specie, gli individui esaminati sono estremamente frammentati, come si può vedere dall'illustrazione.

Famiglia Cuspidariidae Dall, 1886
Genere *Cuspidaria* Nardo, 1840
Cuspidaria cuspidata (Olivi, 1792)
(Fig. 4C, D)

Tellina cuspidata Olivi, 1792: p. 101, tav. 4, fig. 3 (*fide* Sacco, 1901).
Neaera cuspidata - Hörnes, 1870: p. 42, tav. 5, figg. 1–2.
Cuspidaria cuspidata - Sacco, 1901: p. 123, tav. 26, figg. 31–34.
Cuspidaria cuspidata - Pavia, 1975: tav. 14, figg. 8–9.
Cuspidaria cuspidata - Cavallo & Repetto, 1992: p. 228, fig. 687.
Cuspidaria cuspidata - Ardovini & Cossignani, 1999: p. 98.
Cuspidaria cuspidata - Chirli & Richard, 2008: p. 104, tav. 23, fig. 8.
Cuspidaria cuspidata - Sosso & Dell'Angelo, 2010: pp. 78, 83.

Osservazioni

Gli esemplari esaminati, se pure frammentati, sono attribuibili a *Cuspidaria cuspidata* soprattutto per le caratteristiche robuste linee di accrescimento.

Classe Scaphopoda Bronn, 1862
Famiglia Dentaliidae Children, 1834
Genere *Paradentalium* Cotton & Godfrey, 1933
Paradentalium sexangulum (Gmelin, 1791)
(Fig. 4E, F)

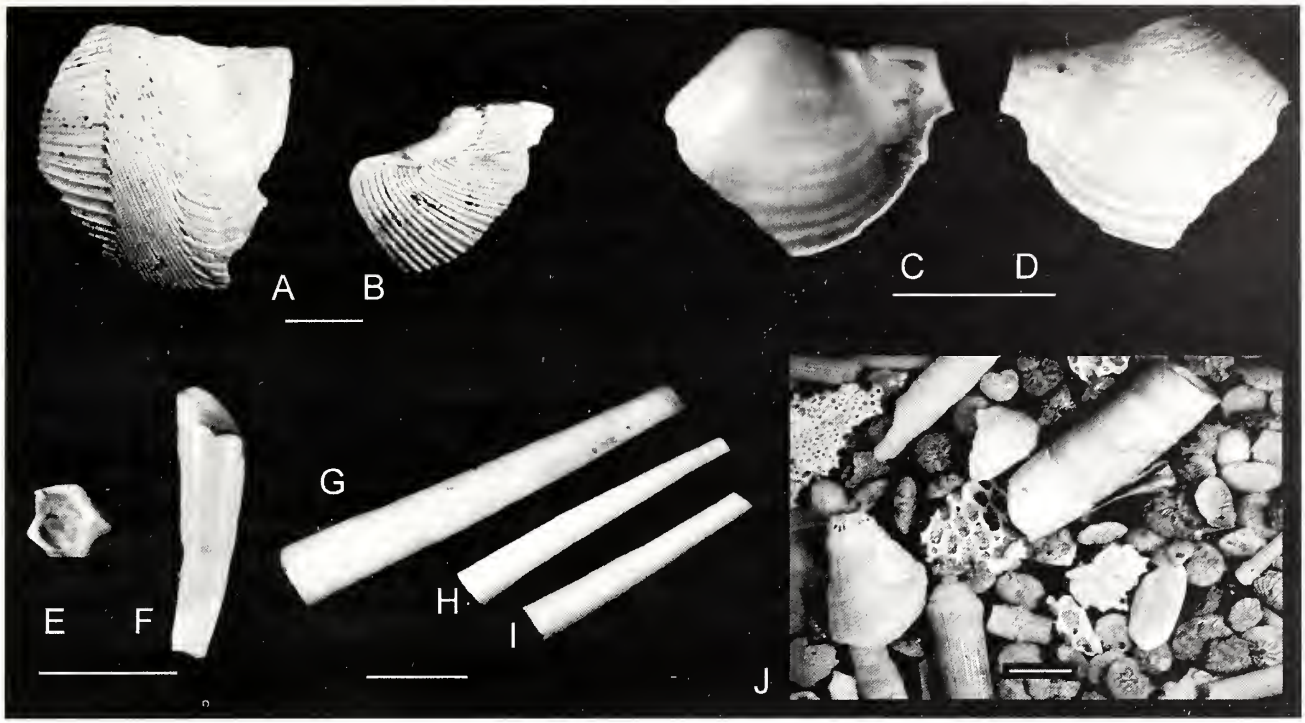

Fig. 4. A, B. *Xylophaga dorsalis* (Turton, 1819). **C, D.** *Cuspidaria cuspidata* (Olivi, 1792). **E, F.** *Paradentalium sexangulum* (Gmelin, 1791). **G-I.** *Fustiaria rubescens* (Deshayes, 1825). **J.** Altri fossili presenti nell'associazione. Linee di scala = 1 mm.

Fig. 4. A, B. *Xylophaga dorsalis* (Turton, 1819). **C, D.** *Cuspidaria cuspidata* (Olivi, 1792). **E, F.** *Paradentalium sexangulum* (Gmelin, 1791). **G-I.** *Fustiaria rubescens* (Deshayes, 1825). **J.** Others taxa in assemblage. Scale bars = 1 mm.

Dentalium sexangulum Gmelin, 1791: p. 3739.
Dentalium sexangulum Schroeter - Sacco, 1897: p. 92, tav. 7, figg. 48–69.
Dentalium sexangulum - Pelosio, 1966: p. 176, tav. 47, figg. 26–28.
Dentalium sexangulum - Caprotti, 1979: p. 221, tav. 3, figg. 1-6.
Dentalium sexangulum - Chirli, 1988: tav. 19, figg. 4, 6.
Dentalium sexangulum - Cavallo & Repetto, 1992: p. 230, fig. 693.
Dentalium sexangulum - Chirli & Richard, 2008: p. 105, tav. 24, figg. 5–8.
Paradentalium sexangulum - Caprotti, 2009: p. 122.
Paradentalium sexangulum - Sosso & Dell'Angelo, 2010: pp. 70, 72.

Osservazioni

Secondo Bernasconi (1996), è una specie distribuita in quantità decrescenti all'aumentare della profondità. Bogi & Cauli (1997), tuttavia, la segnalano, come "molto comune", in un'associazione riferibile alla parte media del circalitorale.

Genere *Fustiaria* Stoliczka, 1868
Fustiaria rubescens (Deshayes, 1825)
(Fig. 4G-I)

Dentalium rubescens Deshayes, 1825: fig. n. t. 363, tav. 16, figg. 23–24 (*fide* Sacco, 1897).
Pseudantalis rubescens - Sacco, 1897: p. 111, tav. 10, figg. 21–23.
Fustiaria rubescens - Caprotti, 1979: p. 241, tav. 12, figg. 3–4.
Pseudantalis rubescens - Pavia, 1991: p. 128, tav. 6, fig. 11.
Fustiaria rubescens - Cossignani & al., 1992: fig. 409.

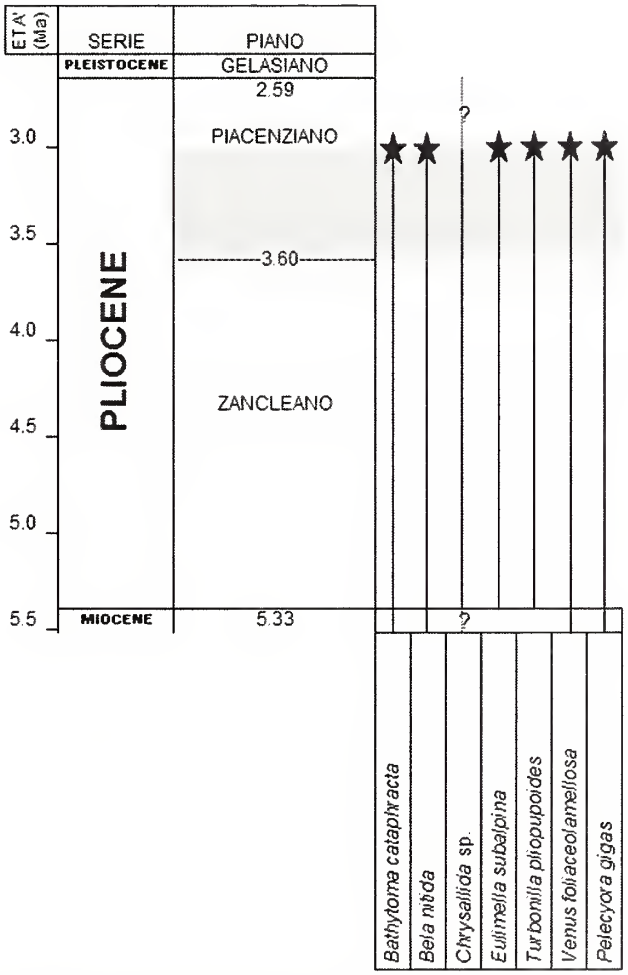

Fig. 5. Inquadramento stratigrafico della malacofauna esaminata.

Fig. 5. Stratigraphic distribution of the molluscan assemblage.

Fustiaria rubescens - Arduino & al., 1995: p. 172.
Fustiaria rubescens - Ardovini & Cossignani, 1999: p. 99.
Fustiaria rubescens - Coppini & al., 2005: p. 49, fig. 3h.
Fustiaria rubescens - Chirli & Richard, 2008: p. 106, tav. 24, fig. 9.
Pseudantalis rubescens - Sosso & Dell'Angelo, 2010: pp. 70, 72.

Osservazioni

È una specie indicativa di accumulo di materia organica (Porcheddu & al., 1997) e, nel Pliocene, era più diffusa a maggiore profondità (Bernasconi, 1996). È lo scafopode maggiormente rappresentato a "Le Conchiglie".

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Record of marine warm-water species and of other "Pliocene survivors" from the Early Pleistocene of Latium (Central Italy)

Luca Santucci*

* Via Cappuccini 6, 02042 Collevecchio (Rieti), Italy, *luca_santucci@libero.it*

Abstract
This paper describes a marine malacofauna from the Early Pleistocene deposits of the Tiber Valley (Latium, Italy). The fossil assemblage includes some warm-water taxa: *Ficus subintermedia* (d'Orbigny, 1852), *Sveltia varicosa* (Brocchi, 1814), *Metula mitraeformis* (Brocchi, 1814) and other molluscan species considered extinct in the Pliocene: *Nassarius clathratus* (Born, 1788), *Turritella aspera* (Mayer, 1866, Sismonda m.s.) and *Belidaphne semicostata* (Bellardi, 1847). The survival of warm-water taxa at the beginning of the Calabrian age could be related to their greater tolerance to a climate regime of higher seasonality, since the Early Piacenzian.

Key words
Central Italy, Tiber Valley, Early Pleistocene, molluscs, palaeoclimatology.

Riassunto
Viene descritta una malacofauna marina raccolta in depositi della media valle del Tevere, a Nord di Collevecchio (Rieti). Tali sedimenti sono attribuibili al Pleistocene inferiore (Calabriano p.p.). La malacofauna raccolta, con 127 specie finora identificate, contiene alcune specie ad affinità calda: *Ficus subintermedia* (d'Orbigny, 1852), *Metula mitraeformis* (Brocchi, 1814), *Sveltia varicosa* (Brocchi, 1814) ed altre specie ritenute estinte nel Pliocene: *Nassarius clathratus* (Born, 1788), *Turritella aspera* (Mayer, 1866, Sismonda m.s.) e *Belidaphne semicostata* (Bellardi, 1847). Tali specie sono state raccolte in livelli di sabbie fini, limose, giallastre, immediatamente al di sotto di peliti sabbiose contenenti alla base una microfauna a *Bulimina etnea* Seguenza, 1862, marker del Pleistocene inferiore. Si esclude la natura rimaneggiata delle specie in esame, per via del buono stato di conservazione dei gusci. La sopravvivenza di specie ad affinità calda, o comunque segnalate sinora solo nel Pliocene, può essere spiegata alla luce dell'evoluzione paleoclimatica del Mar Mediterraneo, interessato, a partire da circa 3,1-3,0 milioni di anni fa, dal passaggio da un regime climatico tropicale ad un regime temperato caldo, con una sempre più marcata stagionalità.

Parole chiave
Italia centrale, Valle del Tevere, Pleistocene inferiore, molluschi, paleoclimatologia.

Introduction

The fossiliferous Late Cenozoic-Quaternary deposits of the Tiber Valley (Latium, Central Italy) have been the subject of many investigations in the past (i.e. Cerulli Irelli & De Angelis d'Ossat, 1898; Tuccimei, 1880, 1889; Terrenzi, 1886. etc.). Recent fossil collectings, carried out in the sandy and sandy-muddy deposits cropping out in the Campana Stream Valley (coordinates: 42°21'18"N; 0°6'20"E), north of Collevecchio (**Fig. 1**), provided an interesting malacofauna including some warm-water taxa as discussed in the present work.

The main feature of the Neogene-Quaternary Mediterranean malacofauna evolution is a marked faunal impoverishment in taxonomic diversity, since the Pliocene, with the progressive disappearance of tropical taxa. This process has been evidenced since the late 70's of the past century (Marasti & Raffi, 1977; Raffi et al., 1985; Raffi & Monegatti, 1993; Monegatti & Raffi, 2001). The faunal impoverishment is related to the progressive shift, in the Mediterranean Sea, from tropical conditions during the Zanclean-early Piacenzian, to the present-day warm-temperate conditions.

Monegatti & Raffi (2001) defined four Mediterranean Pliocene Molluscan Units (MPMUs), each bounded by disappearance events of warm-water bivalves, which can be related to distinct periods in the climatic-oceanographic evolution of the Mediterranean (**Fig. 2**). However, for most species of gastropods is not yet possible to provide a detailed picture of the times of disappearance with respect to these faunal units (Monegatti & Raffi, 2001; Monegatti et al., 2002).

The Calabrian Mediterranean malacofauna is characterized by the gradual and discontinuous appearance of "Boreal Guests" and the disappearance of Pliocene warm-water survivors (Raffi, 1986).

The setting of the middle Tiber Valley marine molluscs faunas in this palaeoclimatic scenario, however, is made difficult by the lack of Boreal Guests records in over 150 years of researches. On the contrary, several warm-water molluscan taxa are here reported from the Tiber Valley deposits.

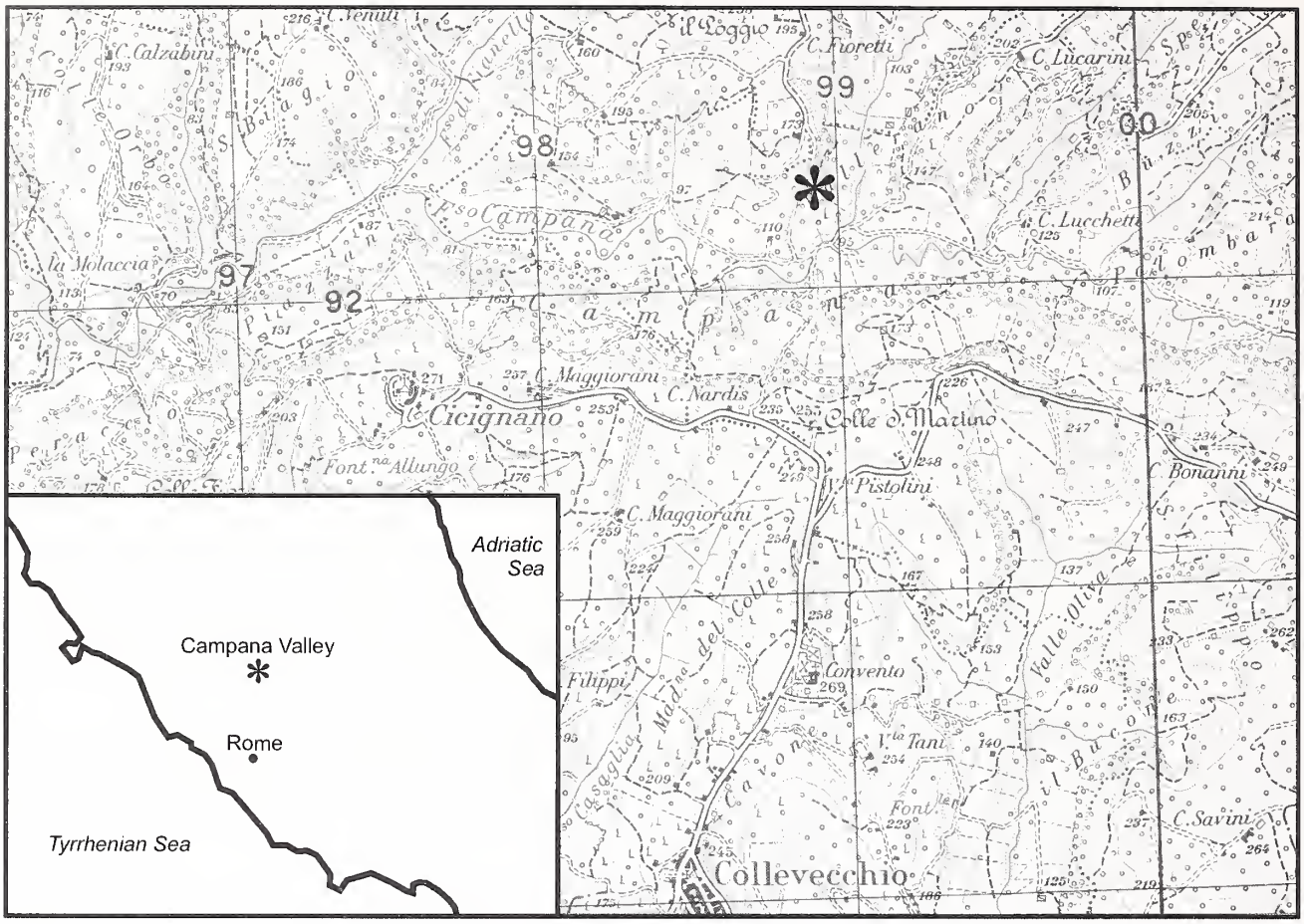

Fig. 1. Location of the study sequence (the asterisk marks the ouctrop).

Fig. 1. Ubicazione della successione studiata (l'asterisco indica l'affioramento).

Geological setting and biostratigraphy

The Chiani-Tevere Basin (Barberi et al., 1994) runs parallel to the present-day Tyrrhenian coastline of Central Italy, bordered by the M. Cetona-M. Rufeno-M. Razzano ridge on the west and the Narnese-Amerina Chain and the Sabini Mountains on the east. The basin is subdivided into two sectors by the NW-SE M. Soratte-M. Cornicolani structural high. In the area, two sedimentary cycles, one Late Zanclean-Early Gelasian and the other Late Gelasian-Early Calabrian, have been recognized (Girotti & Mancini, 2003; Mancini et al., 2004). The investigated succession belongs to the Late Gelasian-Early Calabrian cycle, in particular to Chiani-Tevere Fm. (Girotti & Mancini, 2003; Mancini et al., 2004). It is comprised between the first and the second prograding clastic wedge, according to the stratigraphic scheme (**Fig. 3**) proposed by Girotti & Mancini (2003).

The most complete succession crops out on the right bank of the Campana River (**Fig. 4**). At the base (127 m above sea level) the section includes a 3 m thick level of yellowish, silty fine sands of shallow water deposition, which gradually gives places to blue-grey sandy pelites. The sandy pelitic level, about 21 m thick, become more sandy upwards, where lignite fragments are frequent. A thin, golden, sandy layer (10 cm thick) in the uppermost part of the sandy pelites, with erosional contact and containing clay chips, is considered as a storm layer and a marker bed in the Campana Valley.

The sequence indicates a shallowing trend, from outer shelf (circalittoral) to inner shelf (infralittoral) settings (Carboni, pers. comm.). The section is closed by yellow sands displaying hummocky cross-bedding, and finally medium sands with flat lamination pointing out a transition from the shoreface to the foreshore environment

Because of the absence or scarcity of most reliable biostratigraphic tools in this part of the Chiani-Tevere Basin, such as calcareous nannofossils or planktonic foraminifers, biostratigraphy is based on benthic foraminifers (Di Bella, 1999; Di Bella et al., 2002).

Fortunately, the muddy horizons of the studied section contains some species, such as *Bulimina marginata* d'Orbigny, 1826, *Bulimina elegans marginata* Fornasini, 1902 and *Bulimina etnea* Seguenza, 1862 (Carboni, pers. comm.). *Bulimina etnea* is considered a good marker for the Calabrian, though its first occurrence is not perfectly calibrated (Vaiani & Venezia, 1999). In the Vrica section, GSSP of the Calabrian Stage this bioevent is placed between the "m" and "n" sapropelic layers (Cita, 2010). According to the geochronologic scale of Lourens et al. (1996) it is dated 1.67 Ma.

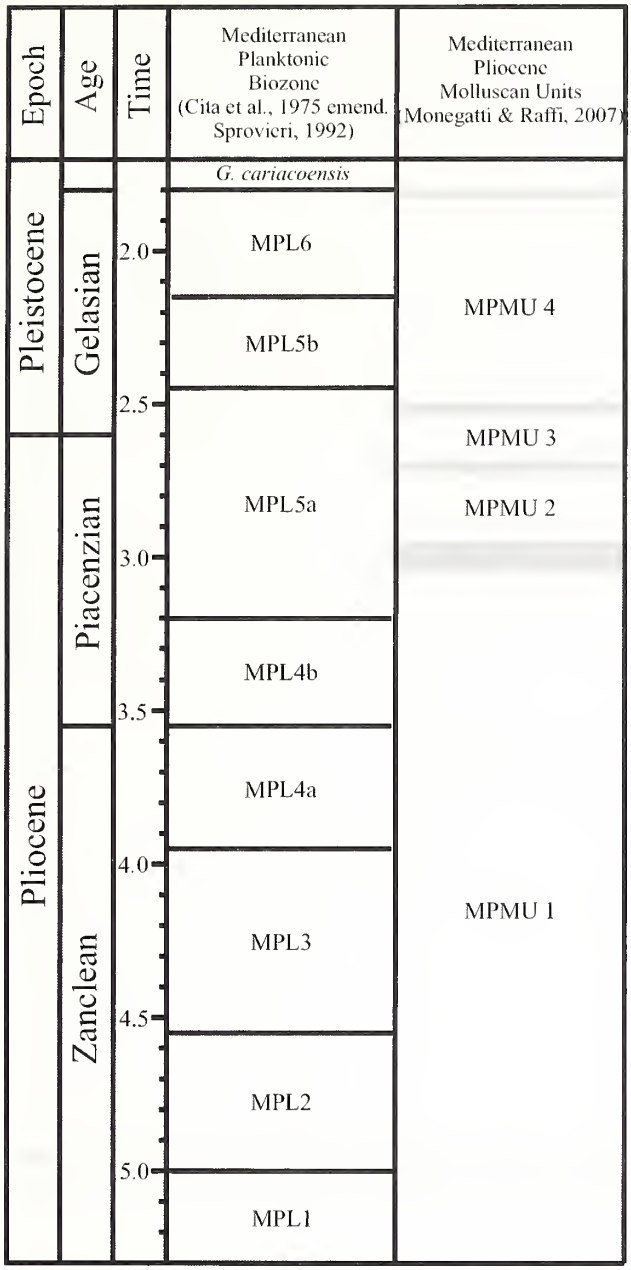

Fig. 2. Molluscan biostratigraphic units in the Mediterranean Pliocene (after Marasti & Raffi, 2007, modified).

Fig. 2. Unità biostratigrafiche a molluschi nel Pliocene del Mediterraneo (da Marasti & Raffi, 2007, modificato).

Material and methods

Fifty samples were collected from the section for the micropaleontological studies. The samples were oven dried at 40°C and sieved through a 0.125 mm mesh. Macrofossils were hand picked on the outcrop and are housed in the author's collection.

The list of extant species belonging to the genera *Ficus* Roeding, 1798, *Sveltia* Jousseame, 1887 and *Metula* H. Adams & A. Adams, 1853 are from the World Register of Marine Species - WoRMS (Appeltans et al., 2012). Data on the present-day geographic distributions of the species were obtained from several online databases: Malacolog Version 4.1.1: Western Atlantic Marine Mollusca (Rosenberg G., 2009), OBIS Indo-Pacific Molluscan Database, Check List of Marine Mollusca (CLEMAM) and gastropods.com.

Results

The list of the molluscs collected and identified has been reported in **Tab. 1**.

The upper part of the yellowish silty sands shows a rich molluscan assemblage, with frequent articulated bivalve shells belonging to *Megaxinus transversus* (Bronn, 1831) and *Lucinoma boreale* (Linné, 1797). The molluscan assemblage from the upper two meters of the overlying blue-grey sandy pelites contains frequent *Venus nux* Gmelin, 1791, *Acanthocardia echinata* (Linné, 1758), *Aequipecten opercularis* (Linné, 1758) and *Nassarius gigantulus* (Michelotti, 1840, Bonelli m.s.), together with *Pelecyora brocchii* Deshayes, 1836, *Miuachlamys varia* (Linné, 1758) and *Glossus humanus* (Linné, 1758). In the middle and upper parts of the sandy pelites *Ostrea lamellosa* Brocchi, 1814, *Modiolus barbatus* (Linné, 1758) and *Spisula subtruncata* Da Costa, 1778 become dominant, indicating a decrease in the palaeobathimetry and the transition from circalittoral to infralittoral environments.

The molluscs assemblages contain three warm-water species, namely *Ficus subintermedia* (d'Orbigny, 1852), *Sveltia varicosa* (Brocchi, 1814) and *Metula mitraeformis* (Brocchi, 1814). Furthermore, some species so far considered extinct in the Pliocene, are also present: *Nassarius clathratus* (Born, 1788), *Turritella aspera* (Mayer, 1866, Sismonda m.s.) and *Belidaphne semicostata* (Bellardi, 1847). Due to the pristine conditions of these species, the hypothesis of their reworking from older levels can be excluded. The warm-water meaning of the genera *Ficus*, *Sveltia* and *Metula* can be inferred from the geographical distribution of their living representatives, and basing on the paleobiogeographical distribution of fossil species in the eastern Atlantic-Mediterranean areas, from the Miocene to the present-day.

Ficus subintermedia (D'Orbigny, 1852) (Fig. 5M, O)

WoRMS reports 9 extant species belonging to the genus *Ficus*. The genus has a worldwide distribution, between 35°N and 35°S latitude.

According to Landau et al. (2004b) in the Middle-Late Miocene of the Mediterranean Sea two species were present: *F. subintermedia* and *F. geometra* (Borson, 1825), whereas in the northern European basins the most frequent species was *F. condita*. One or possibly two distinct species occurred in the Miocene of Germany. The specimens from the Paratethys deposits attributed to *F. geometra* may be related to other species.

In the Early Piacenzian, only two species were still present: *F. subintermedia*, reported from Northern Italy (Brunetti & Vecchi, 2005) and Portugal (Landau et al., 2004b), and *F. geometra*, limited to the Mediterranean (Sacco, 1890; Caprotti, 1973).

According to Landau et al. (2004b), who reviewed the genus *Ficus* in the European Neogene, the Mediterranean Pliocene populations generally referred to as *Ficus cou-*

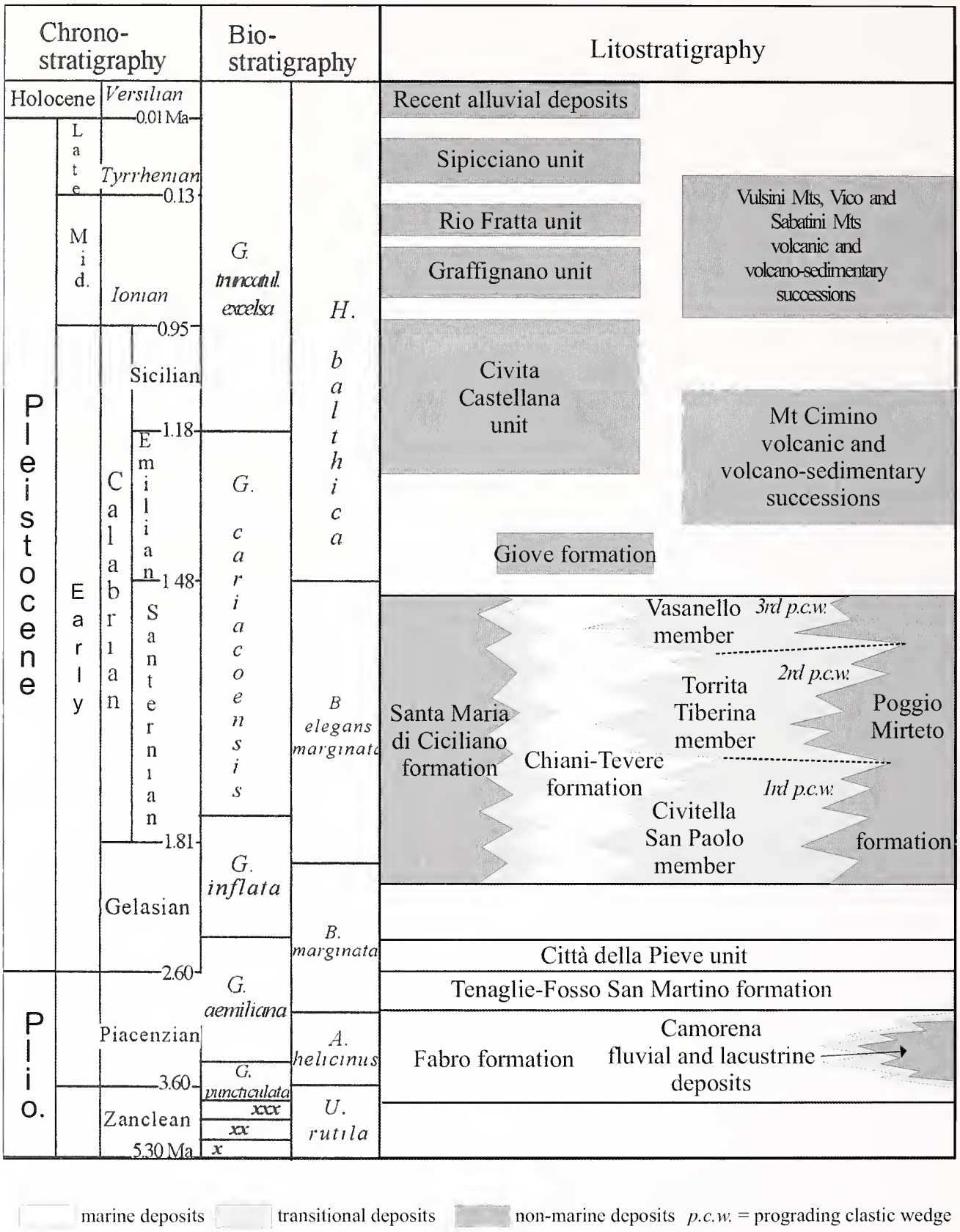

Fig. 3. Litostratigraphic, biostratigraphic and chronostratigraphic scheme of the middle Tiber Valley area (after Mancini & Girotti, 2003, modified).

Fig. 3. Schema litostratigrafico, biostratigrafico e cronostratigrafico della media Valle del Tevere (da Mancini & Girotti, 2003, modificato).

Species	silty sand	clayey silt
Classis BIVALVIA		
Nucula placentina Lamarck, 1819	X	
Nucula sulcata Bronn, 1831		X
Saccella commutata (Philippi, 1844)	X	
Lembulus pella (Linné, 1767)	X	
Dyolia mendax (Meneghini in Appelius, 1870)	X	X
Arca noae Linné, 1758	X	
Ambrogia mytiloides (Brocchi, 1814)		X
Anadara darwini (Mayer, 1868)	X	
Anadara pectinata (Brocchi, 1814)	X	X
Striarca lactea (Linné, 1758)	X	
Limopsis minuta (Philippi, 1836)	X	
Glycymeris insubrica (Brocchi, 1814)	X	
Modiolus barbatus (Linné, 1758)		X
Pecten jacobaeus (Linné, 1758)	X	
Aequipecten opercularis (Linné, 1758)		X
Talochlamys multistriata (Poli, 1795)	X	
Mimachlamys varia (Linné, 1758)	X	X
Flexopecten glaber (Linné, 1758)	X	X
Annusium cristatum (Bronn, 1827)	X	
Spondylus gaederopus Linné, 1758	X	
Anomia ephippium Linné, 1758	X	X
Pododesmus patelliformis (Linné, 1761)	X	X
Ostrea lamellosa Brocchi, 1814		X
Megaxinus transversus (Bronn, 1831)	X	
Myrtea spinifera (Montagu, 1803)	X	
Lucinoma boreale (Linné, 1797)	X	
Chama gryphoides Linné, 1758	X	
Chama placentina Defrance, 1817	X	X
Pseudochama gryphina (Lamarck, 1819)	X	
Cardita calyculata (Linné, 1758)	X	
Cardites antiquatus pectinatus (Brocchi, 1814)	X	
Glans intermedia (Brocchi, 1814)	X	
Cardium indicum Lamarck, 1818	X	X
Acanthocardia bianconiana (Cocconi, 1873)	X	
Acanthocardia echinata (Linné, 1758)	X	X
Plagiocardium papillosum (Poli, 1791)	X	X
Trachycardium multicostatum (Brocchi, 1814)	X	
Mactra stultorum (Linné, 1758)	X	
Spisula subtruncata (Da Costa, 1778)		X
Tellina cf. *donacina* (Linné, 1758)	X	X
Tellina compressa Brocchi, 1814	X	
Tellina serrata (Renier, 1804)	X	
Abra prismatica (Montagu, 1808)	X	
Solecurtus scopula (Turton, 1822)	X	
Azorinus chamasolen (Da Costa, 1778)	X	X
Glossus humanus (Linné, 1758)		X
Venus nux Gmelin, 1791	X	X
Chamelea gallina (Linné, 1758)		X
Chamelea lamellosa (De Rayneval, Van den Hecke & Ponzi, 1854)	X	
Timoclea ovata (Pennant, 1777)	X	X
Gouldia minima (Montagu, 1803)	X	
Pelecyora brocchii (Deshayes, 1836)		X
Corbula gibba (Olivi, 1792)	X	X
Panopea glycimeris (Born, 1778)	X	
Classis GASTROPODA		
Diodora italica (Defrance, 1820)	X	
Clelandella miliaris (Brocchi, 1814)	X	
Diloma patulum (Brocchi, 1814)	X	
Bolma rugosa (Linné, 1758)	X	X
Cerithium varicosum (Brocchi, 1814)	X	X
Cerithium vulgatum (Bruguière, 1792)	X	
Bittium latreillei (Payraudeau, 1826)	X	
Turritella tornata (Brocchi, 1814)	X	
Turritella spirata (Brocchi, 1814)	X	
Turritella aspera (Mayer, 1866 ex Sismonda m.s.)	X	
Turritella tricarinata (Brocchi, 1814)	X	

Species	silty sand	clayey silt
Alvania beani (Hanley in Thorpe, 1844)	X	
Aporrhais pespelecani (Linné, 1758)	X	
Aporrhais uttingeriana (Risso, 1826)	X	X
Calyptraea chinensis (Linné, 1758)	X	X
Crepidula gibbosa Defrance, 1818		X
Crepidula unguiformis Lamarck, 1822	X	
Xenophora crispa (König, 1825)	X	
Capulus ungaricus (Linné, 1758)	X	X
Petaloconchus glomeratus (Linné, 1758)	X	X
Serpulorbis arenaria (Linné, 1767)	X	
Trivia arctica (Pulteney, 1789)	X	
Erato voluta (Montagu, 1803)	X	
Cochlis raropunctata raropunctata (Sasso, 1827)	X	X
Euspira catena (Da Costa, 1778)	X	X
Euspira macilenta (Philippi, 1844)	X	
Ficus subintermedia (d'Orbigny, 1852)	X	
Galeodea echinophora (Linné, 1758)	X	X
Phalium saburon (Bruguière, 1792)	X	
Dizoniopsis bilineata (Hoernes, 1848)	X	
Epitonium commune (Lamarck, 1822)	X	X
Melanella polita (Linné, 1758)	X	X
Niso eburnea (Risso, 1826)	X	
Bolinus brandaris (Linné, 1758)	X	
Hexaplex rudis (Borson, 1821)	X	
Hexaplex trunculus (Linné, 1758)	X	
Muricopsis cristata (Brocchi, 1814)	X	
Hadriania oretea (De Gregorio, 1884)	X	X
Buccinulum corneum (Linné, 1758)	X	
Pollia dorbignyi (Payraudeau, 1826)	X	
Metula mitraeformis (Brocchi, 1814)	X	
Fasciolaria lawleyana (d'Ancona, 1872)	X	
Nassarius gigantulus (Michelotti, 1840, Bonelli m.s.)	X	X
Nassarius incrassatus (Stroem, 1768)	X	X
Nassarius serraticosta (Bronn, 1831)	X	
Nassarius musivus (Brocchi, 1814)	X	
Nassarius macrodon (Bronn, 1831)	X	
Nassarius clathratus (Born, 1788)	X	X
Nassarius mutabilis (Linné, 1758)	X	
Nassarius lima (Dillwyn, 1817)	X	
Mitra cf. *fusiformis* (Brocchi, 1814)	X	
Vexillum pyramidella (Brocchi, 1814)	X	
Vexillum ebenus (Lamarck, 1811)	X	
Sveltia varicosa (Brocchi, 1814)	X	X
Conus cf. *mediterraneus* Hwass in Bruguière, 1792	X	
Haedropleura septangularis (Montagu, 1803)	X	
Bela brachystoma (Philippi, 1844)	X	
Agathotoma angusta (Jan, 1842)	X	
Mangelia attenuata (Montagu, 1803)	X	
Mangelia unifasciata (Deshayes, 1835)	X	
Neoguraleus hispidulus (Jan in Bellardi, 1847)	X	X
Raphitoma echinata (Brocchi, 1814)	X	
Belidapline semicostata (Bellardi, 1847)	X	
Clathurella gracilis (Montagu, 1803)	X	X
Pyramidella plicosa Bronn, 1838	X	X
Odostomia conoidea (Brocchi, 1814)	X	X
Turbonilla rufa (Philippi, 1836)	X	X
Retusa truncatula (Bruguière, 1792)	X	
Cylichnina umbilicata (Montagu, 1803)	X	
Ringicula auriculata (Ménard de la Groye, 1811)	X	X
Ringicula buccinea (Brocchi, 1814)	X	X
Classis SCAPHOPODA		
Antalis inaequicostatum Dautzenberg, 1891	X	X
Episiphon rubescens (Deshayes, 1825)	X	

Tab. 1. Molluscan species from the study sequence.

Tab. 1. Elenco della malacofauna nella successione studiata.

dita (Brongniart, 1823) should be considered as a distinct species, i.e. *Ficus subintermedia*.
According to Verhaeghe & Poppe (2000), the living Indo-Pacific specimens ascribed at *F. subintermedia* d'Orbigny are not conspecific with the European Neogene fossils and should be referred to *F. ficus* (Linné, 1758).

Sveltia varicosa (Brocchi, 1814) (Fig. 5G, H)

WoRMS reports 6 extant species for the genus *Sveltia*, with an intertropical distribution, between 30°N and 30°S.
In the Middle-Late Miocene, *Sveltia* was present with four species at least in the North Sea Basin, five or six species in the Atlantic basins of France, and six species at least in the Mediterranean (Brunetti et al., 2011).
In the Zanclean, *Sveltia* is represented by only two species in the Mediterranean, *S. varicosa* and *S. lyrata* (Brocchi, 1814), and by a single species in the North Sea, *S. jonkairiana* (Nyst, 1835) (Brunetti et al., 2011).
S. varicosa was recently recorded in the Calabrian of Rhodes (Chirli & Linse, 2011), whereas *S. lyrata* is known from the Calabrian of Tuscany (Menesini & Ughi, 1983). As a living species it is known from West Africa (Verhecken, 2007).
In the Po basin the extinction of *Sveltia varicosa* occurred in MPL5a zone, which is referable to the MPMU2 (Monegatti et al. 1997; Monegatti et al., 2002). According to Brunetti et al. (2011), this species was very common in the Zanclean-Piacenzian, rare in the Gelasian, and not present in the Calabrian.

Metula mitraeformis (Brocchi, 1814) (Fig. 5C, D)

According to WoRMS, *Metula* includes 28 living species distributed between 30°N and 35°S latitude.
In the European Middle-Late Miocene, *Metula* is represented by *M. mitraeformis* with a distribution limited to the Mediterranean Basin, and by a similar form, or perhaps conspecific, *M. subuitraeformis* d'Orbigny, 1852, known from Aquitaine, Germany, Holland and Vienna basins (Malatesta, 1974).
M. mitraeformis was also present in the Mediterranean Pliocene, in the MPL6 zone, related to MPMU4 (Monegatti et al., 1997). This is the first Calabrian record for this species.
Bouchet (1988) considered *M. mitraeformis* the direct ancestor to *M. africana* Bouchet, 1988, described from off West Africa.
For the following species, the data on their stratigraphic distribution are scarce, not allowing a well defined palaeoclimatic meaning to be assessed. Their distribution was thought to be limited to the Piacenzian (*Belidaphne semicostata*), or the Gelasian (*Nassarius clathratus* and *Turritella aspera*).

Nassarius clathratus (Born, 1788) (Fig. 5I, L)

According to Brunetti & Vecchi (2005), this species appeared in the Early Miocene of France. In the Pliocene it

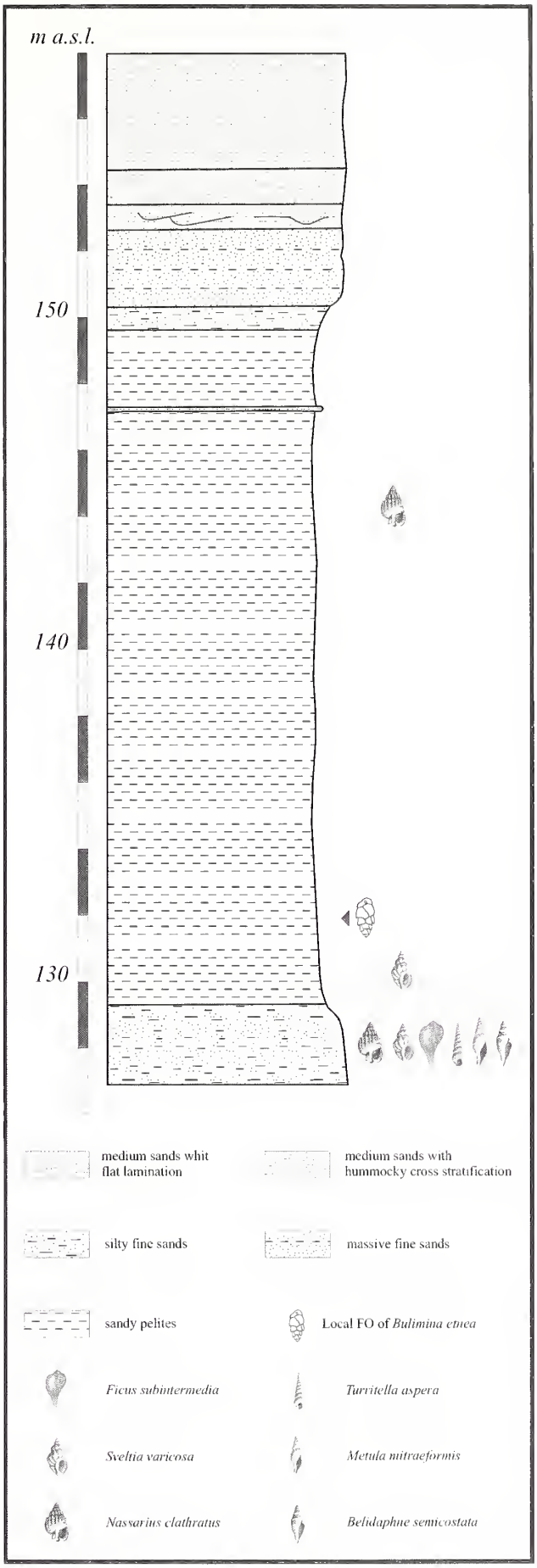

Fig. 4. Litostratigraphy of the investigated succession.

Fig. 4. Litostratigrafia della successione studiata.

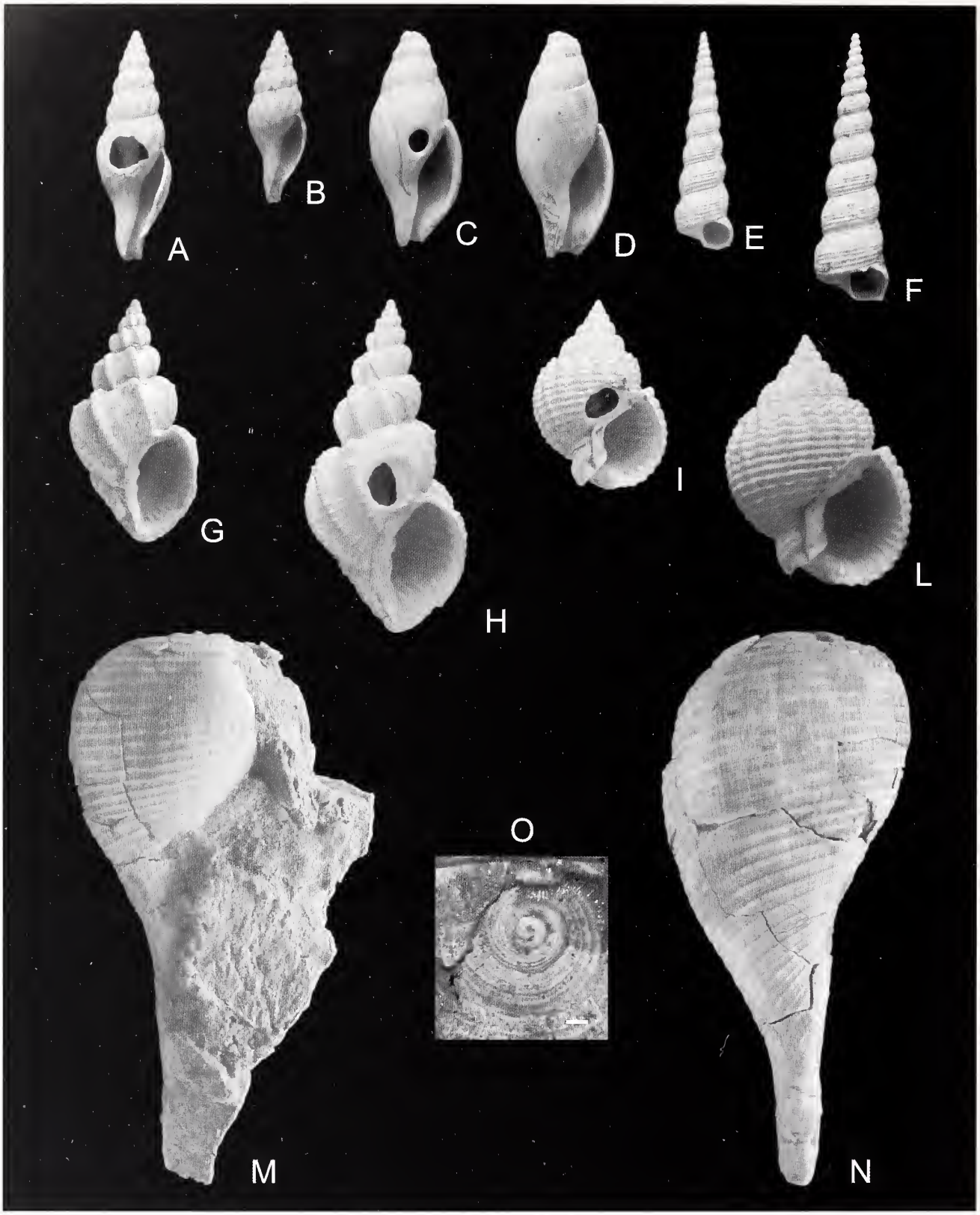

Fig. 5. A, B. *Belidaphne semicostata* (Bellardi, 1847). **A.** Montebuono (Rieti), H = 20 mm (coll. Santucci). **B.** Tarano (Rieti), H = 15 mm (coll. Santucci). **C, D.** *Metula mitraeformis* (Brocchi, 1814). **C.** Tarano (Rieti), H = 25.2 mm (coll. Santucci). **D.** Montebuono (Rieti), H = 26.3 mm (coll. Santucci). **E, F.** *Turritella aspera* (Mayer, 1866, Sismonda m.s.). **E.** Tarano (Rieti), H = 19.2 mm (coll. Santucci). **F.** Tarano (Rieti), H = 26.2 mm (coll. Santucci). **G, H.** *Sveltia varicosa* (Brocchi, 1814). **G.** Montebuono (Rieti), H = 26.3 mm (coll. Santucci). **H.** Montebuono (Rieti), H = 38.4 mm (coll. Santucci). **I, L.** *Nassarius clathratus* (Born, 1788). **I.** Montebuono (Rieti), H = 21.8 mm (coll. Santucci). **L.** Montebuono (Rieti), H = 29.1 mm (coll. Santucci). **M-O.** *Ficus subintermedia* (d'Orbigny, 1852). **M, N.** Tarano (Rieti), H = 96 mm, apertural and dorsal view (coll. Santucci). **O.** Tarano (Rieti), apical whorls (coll. Santucci) (scale bar = 1 mm).

Fig. 5. A, B. *Belidaphne semicostata* (Bellardi, 1847). **A.** Montebuono (Rieti), H = 20 mm (coll. Santucci). **B.** Tarano (Rieti), H = 15 mm (coll. Santucci). **C, D.** *Metula mitraeformis* (Brocchi, 1814). **C.** Tarano (Rieti), H = 25,2 mm (coll. Santucci). **D.** Montebuono (Rieti), H = 26,3 mm (coll. Santucci). **E, F.** *Turritella aspera* (Mayer, 1866, Sismonda m.s.). **E.** Tarano (Rieti), H = 19,2 mm (coll. Santucci). **F.** Tarano (Rieti), H = 26.2 mm (coll. Santucci). **G, H.** *Sveltia varicosa* (Brocchi, 1814). **G.** Montebuono (Rieti), H = 26,3 mm (coll. Santucci). **H.** Montebuono (Rieti), H = 38,4 mm (coll. Santucci). **I, L.** *Nassarius clathratus* (Born, 1788). **I.** Montebuono (Rieti), H = 21,8 mm (coll. Santucci). **L.** Montebuono (Rieti), H = 29,1 mm (coll. Santucci). **M-O.** *Ficus subintermedia* (d'Orbigny, 1852). **M, N.** Tarano (Rieti), H = 96 mm, vista aperturale e dorsale (coll. Santucci). **O.** Tarano (Rieti), giri apicali (coll. Santucci) (scala = 1 mm).

reached a pan-European distribution, from England to Mediterranean, with a last occurrence in the Early Pleistocene of Sicily (Monte Navone), where the species was recorded by Di Geronimo (1969). According to Monegatti et al. (1997), *Nassarius clathratus* was still present in the Gelasian (MPL6 zone), related to MPMU4.
According to Di Geronimo (1975), the specimens from Monte Navone show the shell characters of *N. clathratus* f. *obtusepercostata* Sacco, 1890 (= *N. clathratus*), but he remarked some small, constant differences in the protoconchs. Size and shape of protoconch are important characters for identification in the "*N. clathratus* species group" (Adam & Glibert, 1976), as well as in most gastropods in the modern systematic views. The identity of the M. Navone specimens thus remains doubtful.

Turritella aspera (Mayer, 1866 ex Sismonda m.s.)
(Fig. 5E, F)

According to Monegatti et al. (1997), *Turritella aspera* is still present in the MPL5b zone and the related molluscan unit (MPMU3). Since its appearance in the Late Miocene, its distribution has been limited to the Mediterranean (Malatesta, 1974; Landau et al., 2004a).
Among the fossil and extant Mediterranean Turritellidae, only *T. tricarinata* Brocchi, 1814 is markedly similar to *Turritella aspera*. The former is an extant species, typical to soft, muddy bottoms where the Coastal Terrigenous Muds biocoenosis thrives (Pérès & Picard, 1964).
According to Allmon (1992), the extinction pattern of the Early Neogene turritellinae in North and Central America was strictly controlled by changes in nutrients, rather than by temperature. Probably, also for the European species *T. aspera* other limiting factors, in addition to temperature, may have played a determinant role in its extinction.

Belidaphne semicostata (Bellardi, 1847)
(Fig. 5A, B)

Belidaphne semicostata has a controversial systematic arrangement. Originally referred to *Raphitoma* Bellardi, 1847, it has been moved among several genera: *Homotoma* Bellardi, 1875, *Defrancia* Millet, 1827, *Bellardiella* Fischer, 1883 and *Daphnella* Hinds, 1844 (Scarponi, 2012, pers. comm). Recently, Vera-Pelaez (2002) erected *Raphitoma semicostata* Bellardi, 1847 as type species of the new genus *Belidaphne* Vera-Pelaez, 2002, including few fossil species from Italy and Spain.
Two species, *Belidaphne desmouliusi* (Bellardi, 1847) and *B. saldubensis* Vera-Pelaez, 2002, are present in the Zanclean-Early Piacenzian of Spain (Vera-Pelaez, 2002), whereas *B. semicostata* and *B. desmouliusi* are present in the Zanclean-Piacenzian of Italy (Bellardi, 1847; Brugnone, 1862; Cipolla, 1914; Chirli, 1997).

Discussion

Considering the Early Pleistocene age of the sequence, as indicated by the presence in the blue-grey sandy pelites of *Bulimina etnea*, and the lack of reworking as evidenced by the good preservation, the presence of warm-water taxa can be explained with their survival up to the Early Pleistocene (Calabrian).
The faunal units MPMU3 and MPMU4 include a typical Mediterranean fauna, even if some warm-water taxa are still present (Monegatti & Raffi, 2001). According to Raffi (1986), the coexistence of Boreal Guests and subtropical taxa in the Mediterranean Early Pleistocene may be better explained by the establishment of a higher seasonality climate regime, rather than by a drop in temperature. In particular, this hypothesis is mainly related to the first phase of Boreal Guests in the Calabrian (Santernian substage).
The discovery of warm-water molluscs taxa in the Early Pleistocene (Calabrian p.p.) fossil assemblages of the Tiber Valley represents an element of newness in the knowledge of Pliocene-Pleistocene marine malacofaunas of Central Italy. Three species, *F. subintermedia*, *S. varicosa* and *M. mitraeformis*, though belonging to tropical-warm temperate affinity families, endured the Pliocene cooling phases which, since 3.0-3.1 Ma, caused the extinction of most warm-water taxa and marked the transition from a climate regime with low amplitude oscillations to a regime with higher amplitude variations (Monegatti & Raffi, 2001). For these species, a greater thermal tolerance can be assumed, compared with the other species of their respective families. The survival in the Early Calabrian of these marine molluscs can be explicated with the model of high seasonality outlined by Raffi (1986) and with the Mediterranean sea-surface paleotemperatures proposed by Monegatti & Raffi (2001).
Finally, the finding of *F. subintermedia*, *S. varicosa*, *M. mitraeformis*, *T. aspera*, *N. clathratus* and *B. semicostata* in Calabrian deposits enlarge the list of the Mediterranean Pliocene survivors.

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On *Cardium textum* Bronn, 1831 (Bivalvia, Cardiidae)

Rafael La Perna (✉) & Mauro D'Abramo

Dipartimento di Scienze della Terra e Geoambientali, Università di Bari, Via Orabona 4, 70125 Bari, Italy (✉) corresponding author, rafael.laperna@uniba.it

Abstract
The species known as *Nemocardium striatulum* (Brocchi, 1814) is based on a misidentification. Recently, a replacement name was proposed for it, *Nemocardium italicum* La Perna & D'Abramo, 2011, but the finding of an older valid synonym, *Cardium textum* Bronn, 1831, demands a nomenclatural update. The correct species' name is *Nemocardium textum* (Bronn, 1831).

Key words
Cardiidae, *Nemocardium*, Plio-Pleistocene, Italy, nomenclature.

Riassunto
[*Su* Cardium textum *Bronn, 1831 (Bivalvia, Cardiidae)*]. La specie nota in letteratura come *Nemocardium striatulum* (Brocchi, 1814) è basata su un'erronea identificazione. Recentemente, per questa specie è stato proposto il nome di sostituzione *Nemocardium italicum* La Perna & D'Abramo, 2011. Esiste però un sinonimo valido più antico, *Cardium textum* Bronn, 1831, per cui il nome della specie in esame è *Nemocardium textum* (Bronn, 1831).

Parole chiave
Cardiidae, *Nemocardium*, Plio-Pleistocene, Italia, nomenclatura.

Introduction

According to a recent revision of the genus *Nemocardium* Meek, 1876 from the Pliocene and Pleistocene of Italy, by La Perna & D'Abramo (2011), *Cardium striatulum* Brocchi, 1814 has been misidentified in the past and modern literature, as *Nemocardium striatulum* (Brocchi, 1814) (Sacco, 1899; Cerulli-Irelli, 1908; Cavallo & Repetto, 1992; Monegatti & Raffi, 2001; Tabanelli, 2008). No material of *C. striatulum* is present in the Brocchi's collection, but a critical review of the original description and illustration (Brocchi, 1814: p. 507, pl. 13, fig. 5) provides strong evidence that it is a *Laevicardium* species, most probably a juvenile of *L. crassum* (Gmelin, 1791). The species which has been reported as *Nemocardium striatulum* actually belongs to *Nemocardium*, but it was described by Calcara (1841: p. 28, pl. 1, fig. 7) from the Pliocene of Altavilla (Sicily) as *Cardium striolatum*. Due to the pre-occupied status of *C. striolatum* Calcara, 1841 by *C. striolatum* Link, 1807, La Perna & D'Abramo (2011) proposed *Nemocardium italicum* as a replacement name. Further literature searches allowed an older, valid synonym to be brought to light, *Cardium textum* Bronn, 1831, as discussed in the present work.

Results and discussion

Cardium textum was described by Bronn (1831: p. 102; species n. 589) on two specimens from "Cq." and "And.", the former standing for Castell'Arquato, the latter for Valle Andona, two classical Pliocene localities in Northern Italy. The "blue clays" cropping out in the area of Castell'Arquato and Lugagnano (Piacenza) are of Middle Pliocene age and represent the historical Piacentian stratotype (Rio et al., 1988; Lirer & Iaccarino, 2011). For this locality, Bronn (1831) indicated the stratigraphic level "d" (p. 5: "*Jüngerer Grobkalk, gelb, sandig, über vorigem*"), probably pointing to the upper part of the Piacentian sequence, consisting of sandy beds (Lirer & Iaccarino, 2011: fig. 39). Material of "*Nemocardium italicum*" from Castell'Arquato was examined and illustrated by La Perna & D'Abramo (2011). Valle Andona is the type locality of the disused Astian stage, whose historical stratotype mainly consists of sandy beds (Lirer & Iaccarino, 2011: fig. 43), Early to Middle Pliocene in age (Sampò et al., 1968).

Bronn described his species as follows: "*C. testa cordiformi inflato-globosa, radiatim striata; striis subtilissimis, numerosissimis, simplicibus: anterioribus texto-undulosis, medianis rectis, posterioribus crassis subtilissime papillosis; interstitiis punctatis, marginibus crenulatis.*

Länge und Breite 6'". Streifen des hinteren Drittheils über 30, des mittleren und vorderen gegen 150.".

This description fits well with *Nemocardium italicum*, but a confirmation of the identity of *C. textum* and its conspecificity with *N. italicum* was given by the examination of two valves from the Bronn collection, on high resolution photographs (**Fig. 1**). The two valves are stored in the Museum of Comparative Zoology, Harvard University, Cambridge, with the catalogue number IPBV-6874 and are labelled "Castell'Arquato". It is not

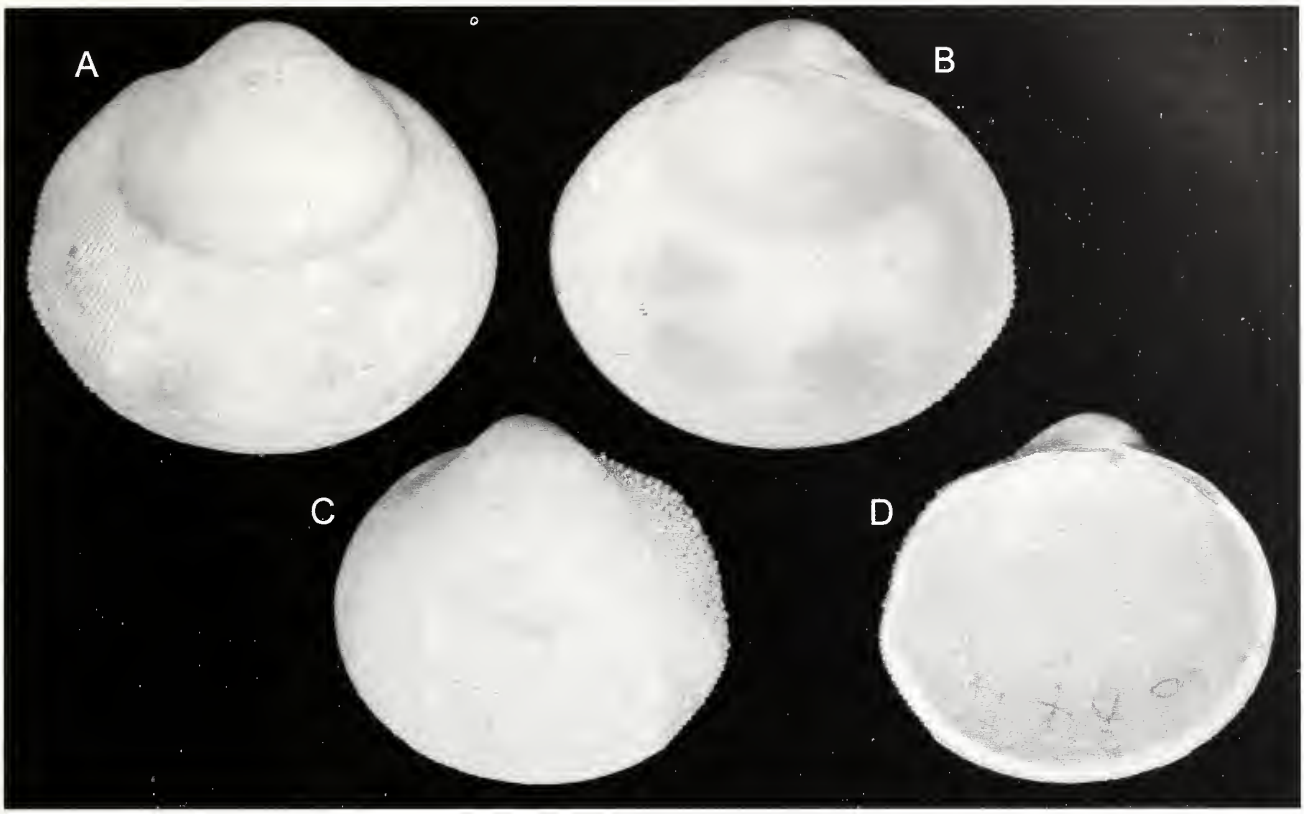

Fig. 1. *Nemocardium textum* (Bronn, 1831). Possible syntypes of *Cardium textum* Bronn, 1831 (Bronn coll., Museum of Comparative Zoology, Harvard University, IPBV-6874). **A**. 11.1 mm (length); **B**. 9.2. mm (length). Courtesy of MCZ.

Fig. 1. *Nemocardium textum* (Bronn, 1831). Possibili sintipi di *Cardium textum* Bronn, 1831 (coll. Bronn, Museum of Comparative Zoology, Harvard University, IPBV-6874). **A**. 11,1 mm (lughezza); **B**. 9,2 mm (lunghezza). Per gentile concessione MCZ.

known if they actually are syntypes of *Cardium textum*, but it is worth remarking that Castell'Arquato is one of the two localities reported in the original description.

Cardium textum was discussed by Pantanelli (1893), on Pliocene material from the malacological collections housed in the Museo di Mineralogia e Geologia of the Modena University. He reported and commented the original description, focusing on the sculpture: "*...non è esatto che le costicine anteriori sieno ondulose, esse sono rettilinee come in tutti i Cardium, però le papille distanti fra loro dalle quali sono ornate, sono disposte in serie ondulose, mentre nella parte posteriore le costicine più grosse e più marcate son coperte di papille uniformemente avvicinate*". Pantanelli remarked that the anterior riblets are not "wavy", as described by Bronn, but regularly straight (i.e. radial), bearing wide spaced, small tubercles which form wavy alignments, whereas the posterior riblets are coarser, with close set, regularly spaced tubercles. As seen in the illustrations reported by La Perna & D'Abramo (2011: fig. 4e, f), the anterior granulations are variable in strength, usually well defined, forming discontinuous wavy ridges, obliquely to commarginally arranged.

Strangely, Pantanelli did not recognize the differences between *Cardium striatulum* and *C. textum*, though he admitted the poor quality of Brocchi's description and illustration.

We are not aware of other citations of *Cardium textum* in the early literature, apart that by Namias (1898), based on the malacological collection from Castell'Arquato housed in the University of Modena, i.e. the same material studied by Pantanelli.

"*Cardium textum* Bronn, 1832" (*sic*) was included in the recent work by Hylleberg (2004: p. 800), with the only remarks "Combination to be revised".

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Synonymies should include only the main references, useful to assess the species identity (e.g. based on material examined and well documented records).

Exemple of systematic hierorchy and synonymy:
Family Cardiidae Lamarck, 1809
Subfamily Cardiinae Lamarck, 1809

Genus *Aconthocordio* Gray, 1853
(type species *Cordium oculeotum* Linné, 1758)

Cordium indicum Lamarck, 1819
(Fig. 1A-D, Fig. 2C)

Cordium hions Brocchi, 1814: p. 508, pl. 13, fig. 6 (non Spengler, 1799).
Cordium indicum Lamarck, 1819: p. 4.
Cordium (Cordium) indicum Lamarck – Fischer-Piette, 1977: p. 112, pl. 10, fig. 4 (type).

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A careful cross-check between bibliographic citation in the text and reference list should be made before submitting the manuscript.

Exemple of citotions:
... reported by Richardson & Smith (1965)
... as known in literature (Ross et al., 1993; Rosenberg, 1995, 1997; Michelini & Andriani, 2000)
... the original illustration (Torwald, 1879: p. 56, pl. 2, fig. 5).

Exemple of references:
Salas C., 1996. Marine Bivalves from off the Southern Iberian Peninsula collected by the Balgim and Fauna 1 expeditions. *Holiotis*, **25**: 33-100.
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Direttore responsabile: Paolo Crovato
e-mail: paolo.crovato@fastwebnet.it

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